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Technologies and Management Strategies for Hazardous Waste Control

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Technologies and Management Strategies for Hazardous Waste Control

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This report presents the analyses, findings, and conclusions of OTA's study of the Federal program for the management of nonnuclear industrial hazardous waste. In conducting the study, OTA analyzed a wide range of views -- from the technical community, industrial sectors which generate hazardous waste, the waste management industry, the environmental community, State and local officials, Federal agencies, and the lay public. As a result of that effort, OTA identified four policy options,beyond maintaining the current Federal program, which could form the basis for an immediate and comprehensive approach to protecting human health and the environment from the dangers posed by mismanagement of hazardous waste. One near-term option addresses the means to improve the technical effectiveness of the current regulatory structure. The other near-term option provides a non-regulatory or market approach to achieving a number of desired goals. Both of these options are compatible with the two longer term options, one of which deals with introducing waste and facility classifications into the regulatory structure, and the other which focuses on achieving greater integration of Federal programs, agencies, and statutes concerned with hazardous waste.

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CONGRESS OF THE UNITED STATES
Office of Technology Assessment
Washington, D.C. 20510

Foreword

This report presents the analyses, findings, and conclusions of OTA's study of the Federal program for the management of nonnuclear industrial hazardous waste*—an issue that has now reached national prominence and widespread congressional attention. OTA's findings and conclusions concerning the technical components of the Federal hazardous waste program complement current activities which have focused more on administrative problems and issues. Our work offers a number of opportunities, at this critical time, for examining solutions to national hazardous waste problems.

This report is the final product of a 3-year effort at OTA. During that time we have contributed extensively to committee deliberations on hazardous waste management—including such issues as Federal exemptions of hazardous waste from regulation, procedures used to select uncontrolled hazardous waste sites for attention under the Superfund legislation, the use and regulation of land disposal techniques, the adequacy of monitoring requirements for land disposal facilities, the adequacy of EPA's risk assessment analyses, and the potential for introducing the relative hazard levels of wastes into Federal regulations. For example, in November 1981 and in April and August 1982, OTA presented testimony to Senate and House committees concerning a number of technical problems in the implementation of Superfund. In April and June 1982, we provided extensive testimony to House and Senate committees on the regulatory exemption of hazardous wastes generated in relatively small quantities (less than 1 metric ton per month); and in July 1982, a staff memorandum was released on this issue. All bills currently being considered for the reauthorization of the Resource Conservation and Recovery Act address this small generator exemption issue which OTA examined in depth.

In conducting the study, OTA analyzed a wide range of views—from the technical community, industrial sectors which generate hazardous waste, the waste management industry, the environmental community, State and local officials, Federal agencies, and the lay public. As a result of that effort, OTA identified four policy options—beyond maintaining the current Federal program—which could form the basis for an immediate and comprehensive approach to protecting human health and the environment from the dangers posed by mismanagement of hazardous waste. One near-term option addresses the means to improve the technical effectiveness of the current regulatory structure. The other near-term option provides a nonregulatory or market approach to achieving a number of desired goals. Both of these options are compatible with the two longer term options, one of which deals with introducing waste and facility classifications into the regulatory structure, and the other which focuses on achieving greater integration of Federal programs, agencies, and statutes concerned with hazardous waste.

The assessment was originally undertaken at the request of the House Committee on Energy and Commerce. The focus of the study was to be on technological options for managing hazardous waste at operating facilities, technical means to address the problem of uncontrolled and possibly abandoned hazardous waste sites, and the technical adequacy of the Federal regulatory program.

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*The term "hazardous waste" means a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may—(A) cause, or signficantly contribute to an increase in mortality, or an increase in serious irreversible, or incapacitating reversible, illness; or (B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

OTA believes that we have provided analyses and policy options which can assist the current efforts to achieve an effective, equitable, and expeditious Federal program to protect the public from the dangers of hazardous waste. This is due in large part to the support, assistance, and cooperation received from many people representing a great diversity of viewpoints on the issues.

John H. Gibbons

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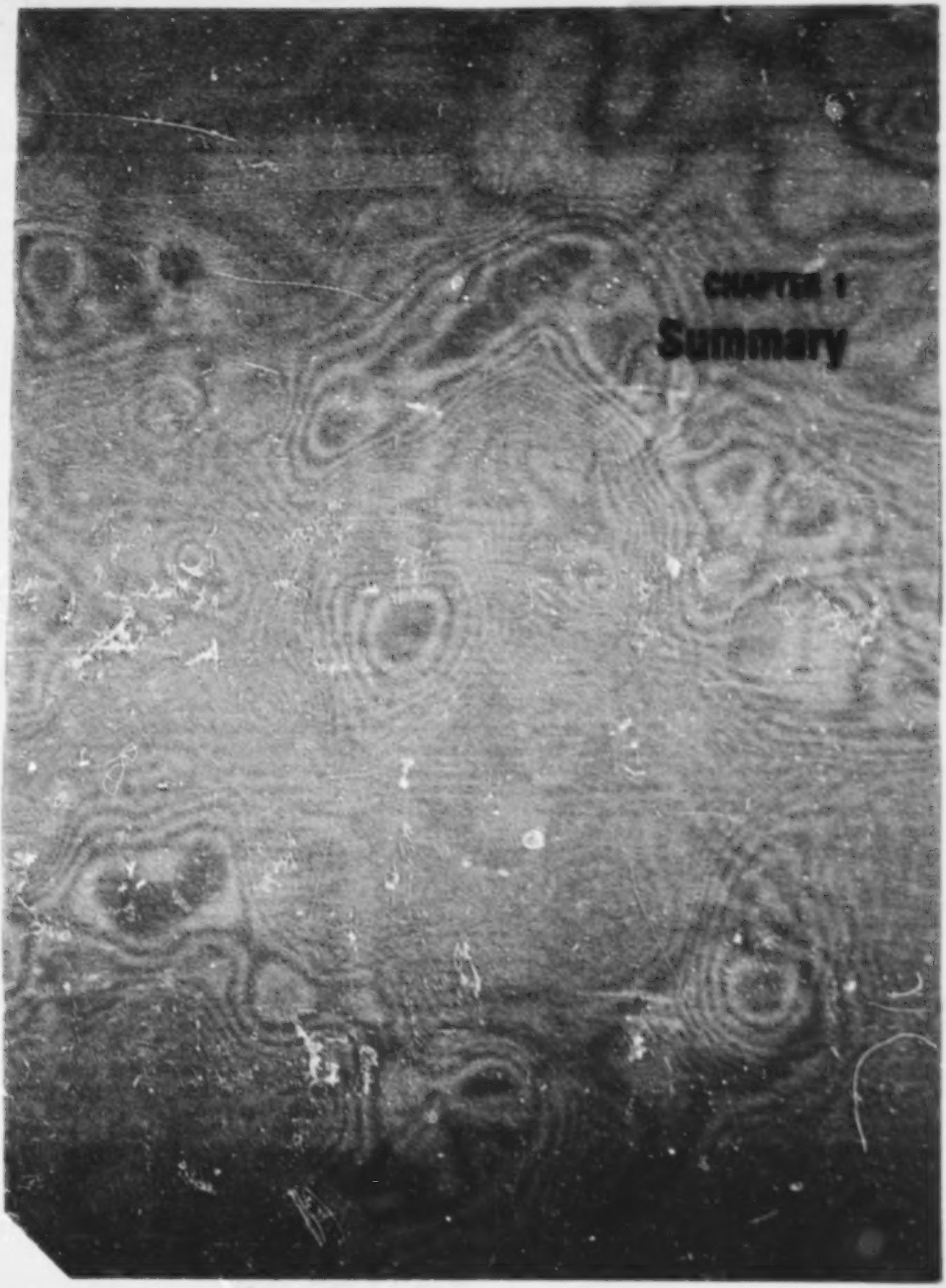

CHAPTER 1

Summary

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CHAPTER 1

Summary

Overview

Newly established Federal regulations for hazardous waste management facilities may not effectively detect, prevent, or control hazardous releases, especially over the longer term. Moreover, some regulatory standards and controls will be set by State authorities, who may not have the resources to make technically complex decisions. **Consistent levels of protection nationwide are not assured.**

In less than a decade the Federal program has advanced State efforts, cleaned up some uncontrolled sites, and assisted industry in improving its waste management. **Nevertheless, data inadequacies conceal the scope and intensity of hazardous waste problems, especially those related to health and environmental effects, and impede effective regulation of wastes and waste management facilities.**

About 255 million to 275 million metric tons (tonnes) of hazardous waste under Federal and State regulation are generated annually. Some States have stricter definitions for hazardous waste than the Federal program, which regulates about 40 million tonnes annually. **Millions of tonnes of federally exempted hazardous waste disposed in sanitary landfills pose substantial risks.** Such exemptions cover most hazardous waste from generators producing less than 1 tonne a month. In addition, large volumes of relatively low-hazard waste such as mining waste and waste generated by the burning of fossil fuels are exempt from Federal regulation.

Land disposal is used for as much as 80 percent of regulated hazardous waste, some of which may remain hazardous for years or centuries. **Inappropriate disposal of hazardous waste on land creates the risk of contaminating the environment, particularly ground water, which could cause adverse health effects.** Federal policies may inadvertently reduce private costs of land disposal by shifting some long-term cleanup and monitoring costs to Government or to society as a whole; the effect may be to retard the adoption of alternatives such as waste reduction and waste treatment. **A key policy issue is: Can unnecessary risks and future cleanup costs be eliminated by limiting the use of land disposal and by making alternatives to it more attractive?**

As their responsibilities mount, States fear reductions in Federal support and seek a stronger policy role. States sometimes cannot raise even the required minimum 10 percent of initial Superfund cleanup costs—and they must assume all future operation and maintenance costs. **Because there are no specific Federal technical standards for the extent of cleanup, and because there is an incentive to minimize initial costs, remedial actions may be taken that will prove ineffective in the long term. When Superfund expires in 1985, many uncontrolled sites still will require attention.**

Actions that enhance public confidence in the equity, effectiveness, and vigorous enforcement of Government programs may reduce public opposition to siting hazardous waste facilities. Opposition also may be reduced by improvement in the dissemination of accurate technical information on issues such as waste treatment alternatives to land disposal.

Five policy options are examined:

1. **Continue with the current program.**
2. **Extend Federal controls** to more hazardous waste, and establish national regulatory standards based on specific technical criteria. Also, restrict disposal of high-hazard waste on land, and improve procedures for permitting facilities and deregulating waste.
3. **Establish Federal fees on waste generators as an economic incentive to reduce the generation of waste and discour-**

age land disposal; impose higher fees on generators of high-hazard waste that are land disposed; provide assistance for capital investments and research and development (R&D) for waste reduction and waste treatment.

4. Study the costs and advantages of **classifying wastes and waste management facilities by degree-of-hazard** to match hazards and risks with levels of regulatory control.
5. Examine the need for greater **integration of Federal environmental programs** to remove gaps, overlaps, and inconsistencies in the regulation of hazardous waste, and to make better use of technical data and personnel.

Substantial Risks and Damages

Uncontrolled and careless disposal of industrial waste became a national concern in the mid and late 1970's. It became evident at many waste sites that mismanagement and indiscriminate dumping of waste were causing harmful substances to be released into the land, water, and air. Waste handlers and the general public alike were threatened with direct exposure to hazardous waste.

It also became increasingly clear that even well-intentioned and presently accepted waste management practices, particularly the use of landfills, surface impoundments, and lagoons, might still constitute substantial threats. These threats arise from the potential slow leakage of waste constituents or leachate* through the soil and into ground water, which is a source of drinking water for many communities.

Before Congress enacted the Resource Conservation and Recovery Act (RCRA) in 1976, relatively few States had regulatory programs dealing with hazardous waste. Experience with conventional forms of industrial and municipal solid waste had given the States little preparation for dealing with hazardous waste, many of which are chemically stable and thus extremely persistent under most conditions.

Studies across the Nation revealed that the disposal of hazardous waste decades earlier had left undetermined, but possibly very large, amounts of dangerous substances in and on the land. Moreover, wastes were leaking from many hazardous waste sites, some of which were closed. RCRA did not effectively deal with these old, often abandoned, sites because it was primarily concerned with proper management and permitting of present and future hazardous waste. In order to deal with the many substantiated and potential hazards posed by uncontrolled hazardous waste sites, Congress passed the Comprehensive Environmental, Response, Compensation, and Liability Act of 1980 (CERCLA), better known as Superfund.

Adverse health effects attributable to hazardous waste remain inadequately documented. However, a 1980 survey by the Environmental Protection Agency (EPA)[1] of 350 uncontrolled hazardous waste sites indicated substantial threats to the public. At the time, these were essentially all the sites for which there was detailed information. There are currently more than 15,000 uncontrolled sites in EPA's Emergency and Remedial Response Information System. The survey found:

- contamination of ground waters and reservoirs, affecting water supplies of 168 communities;
- contamination of drinking water wells leading to closure of at least 468 individual wells; and
- a total of 108 other adverse incidents, including damage to human health, natural

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*Leachate is liquid resulting from the interaction of water with waste. The source of the water may be rain, inflow of ground or surface waters, or other waste.

[1] "Damages and Threats Caused by Hazardous Waste Sites" (Washington, D.C.: Environmental Protection Agency, 1980).

habitats, fish and livestock, crops, sewer systems, and soils.

Furthermore, an unreleased EPA study, in progress for several years, indicates there are 80,263 sites in the Nation with contaminated surface impoundments (pits, ponds, and lagoons).[2] Ninety percent are believed to pose at least a potential threat of ground water contamination. Another unreleased EPA study reports that testing of underground drinking water supplies in 954 cities found contamination in 29 percent. All the affected areas had populations of more than 10,000.[3] Leaching of toxic substances from waste landfills is believed to be a contributory factor in these cases.

Long-term health effects from exposure to hazardous waste are uncertain, but they may be serious. For example, in one case of contaminated drinking water (associated with a hazardous waste dump in Hardeman County, Tenn.), the levels of carbon tetrachloride were so high that they exceeded proposed water quality criteria by a factor of 10,000.[4] EPA has said that of the 418 uncontrolled hazardous waste sites in the Nation that need priority attention, 347 pose direct threats to drinking water supplies and could cause birth defects, cancer, and other diseases.[5]

Although information is scanty on the amounts and types of releases, many hazardous wastes are persistent, mobile, and highly toxic. It is possible that large segments of the population are being exposed to releases of hazardous waste constituents. As much as 80 percent of federally regulated hazardous waste—at least 30 million tonnes per year—are being placed in or on the land. An even greater percentage of the 255 million to 275 million tonnes of hazardous waste under Federal and State regulation may be land disposed. Therefore, under current practice, 1 tonne of hazardous waste is added to the environment for every person in the Nation every year. The accumulation from past decades of industrial activity is equivalent to several tonnes of hazardous waste for every person in the Nation. Furthermore, waste management techniques other than land disposal, such as the burning of waste in boilers, cement kilns, and incinerators, may be releasing hazardous substances into the environment.

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[2] As reported in *The New York Times*, Dec. 30, 1982.

[3] As reported in *Engineering Times*, September 1982.

[4] Samuel S. Epstein, et al., *Hazardous Waste in America*, Sierra Club Books, 1982.

[5] As reported in *The Washington Post*, Dec. 21, 1982.

The Tradeoff Between Near- and Long-Term Costs

The economic costs of hazardous waste are substantial. Industry and governments are currently spending $4 billion to $5 billion annually to manage regulated hazardous waste. Assuming a continuation of present Federal RCRA and CERCLA programs and modest increases in hazardous waste generation, annual costs are estimated to rise to more than $12 billion (in 1981 dollars) in 1990. If more wastes are regulated, if more major cleanup actions are required, and if compensation is required for damages to health and environment, then future costs could be much greater. Government spending will increase substantially as RCRA and CERCLA implementation becomes more intensive.

The cost of cleaning up uncontrolled sites and compensating for damages to human health and the environment calls for consideration of the full "lifecycle" costs of managing hazardous waste. From an economic perspective, the overriding hazardous waste issue of today is: **Would it be more prudent and effective in the long term to increase the stringency of current land disposal regulations and encourage the use of alternatives to land disposal, even though near-term costs might be increased?** Attempting to minimize present costs will almost certainly lead to a transfer of greater costs to the future. Moreover, failure to improve waste management in the near term would surely lead to unacceptable health and environmental effects in the long term. It should be stressed that the language of RCRA precludes balancing costs and risks; rather, it places sole emphasis on the protection of public health and the environment.

The cost to assess and clean up an uncontrolled site ranges from several hundred thousand dollars to tens of millions of dollars. For example, the cost to clean up one site in Seymour, Ind., has been estimated at $22.7 million. To clean up four sites in St. Louis, Mich., one company has agreed to spend $38.5 million. Hydrogeologic investigations to define the extent of ground water contamination can cost from $25,000 to $250,000. The average cost for cleaning up and containing contaminated ground water ranges from $5 million to $10 million a site; the cost of totally restoring a badly contaminated aquifer to potable quality could be 10 times the average cost.

To clean up a substantial fraction of the more than 15,000 presently known uncontrolled hazardous waste sites is likely to cost, in public and private spending, a total of $10 billion to $40 billion. This should be compared with the estimated $1.6 billion to be collected under CERCLA by 1985. CERCLA funds are meant to be used for cleaning up uncontrolled sites where no responsible party can be identified, and for advancing funds for cleanup before recovery from responsible parties is made. The cost of cleaning up known sites is not likely to be the end of the expense. Still more uncontrolled sites are being discovered, and probably some are being created by current practices and exemptions.

It is generally acknowledged that, even with the new stricter RCRA regulations in place, eventual releases of hazardous constituents from land disposal facilities are highly probable. Greater use of waste treatment alternatives is, therefore, a major issue, although they too, if not regulated effectively, can release hazardous constituents to the environment. Yet greater use of alternatives to land disposal—treatment, recycling, and especially more investment in waste reduction—could increase industry's near-term costs significantly, perhaps by as much as 50 to 100 percent. Years or decades from now, cleaning up a site from which there are hazardous releases, and compensating victims, might cost 10 to 100 times the additional costs incurred today to prevent releases of hazardous materials.

For example, in the case of Love Canal, it has been estimated that disposal of the waste dumped there decades ago—according to the standards and practices of today—would have cost $2 million (in 1979 dollars)* versus $36 million for remedial action already spent through 1980. Ultimate costs for remedial action are expected to exceed $100 million; in addition about $2 billion in lawsuits have been filed by persons claiming damages.

EPA estimates that the average cost of disposing of hazardous waste in compliance with the new RCRA regulations is about $90 per tonne. The EPA estimate of the cost of cleaning up improperly dumped waste is up to about $2,000 per tonne. In addition, much of the burden of future costs would likely fall on the general public. Costs incurred today by improved management of hazardous waste would be borne, more equitably, by waste generators and by consumers of "hazardous waste-intensive" products.

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*This is not to suggest that the technical factors alone were responsible for the Love Canal problems.

Scope of This Study

As requested by Congress, this assessment focuses on:

1. information and analysis on the use and development of technologies that can improve hazardous waste management through:
    a. reduction of the volume and hazard level of waste generated;
    b. better management of the risks associated with waste treatment and disposal; and
    c. the cleanup of uncontrolled waste sites;
2. analysis of the potential benefits and costs of a framework based on scientific criteria to judge the relative degree of hazard of wastes and risks from management facilities; and
3. evaluation of current regulatory programs, particularly with regard to technical information and issues.

The primary focus of this assessment is on management strategies, technological options, and the technical components of a Federal hazardous waste regulatory program that would protect human health and the environment. More attention has been given to issues and problems related to RCRA than to CERCLA. This assessment is an analytical study to provide a basis for policy discussion and examination of legislative options by Congress; it is not an attempt to write new regulations for the executive branch or the individual States. Strictly administrative issues and problems, such as enforcement, permitting, and delegation of authority to States, are considered only to the extent that they relate to the study's primary technical focus. Transportation and accidental spills of waste are not considered in any substantial way. Nor has it been possible to examine issues and problems unique to Federal hazardous waste facilities. A part of this analysis is concerned with examining the procedures for better assessing the nature and intensity of, and monitoring for, adverse effects on human health and the environment from releases of hazardous waste or their constituents into the air, land, and/or water. Major attention, however, is not given to substantiating, documenting, or critically evaluating health and environmental data.

Key Issues and Findings

The following "issues and findings" section is a partial summary of the full report, emphasizing issues of particular interest to Congress and areas of special concern in the development of the Federal hazardous waste program. It presents the major analytical findings of chapters 4 through 7. A summary of chapter 3 (Policy Options) follows this section.

ISSUE 1

Is the existing health, environmental, and management information an adequate basis for an effective national hazardous waste control program? To what extent are currently generated hazardous wastes subject to regulation by Federal and State programs?

FINDING

Although EPA and the States are improving data collection, there are major uncertainties on how much hazardous waste is generated, the types and capacities of existing waste management facilities, the number of uncontrolled waste sites and their hazard levels, and on health and environmental effects of hazardous waste releases. Data inadequacies conceal the scope and complexity of the Nation's hazardous waste problems, and impede effective control. Large-scale exemptions from the Federal program make the coverage of Federal regulation much narrower than that of the States (see ch. 4).

Waste Definition.—An adequate definition of hazardous waste is crucial to an effective hazardous waste management effort. EPA regulations currently define a subset of "solid wastes"* that are controlled under RCRA as "hazardous wastes." In addition, some hazardous wastes are regulated under environmental statutes other than RCRA. EPA's definition of "hazardous waste" covers only these federally regulated wastes. Some States, perceiving inadequacies in the Federal definition of hazardous waste, use different and broader definitions for purposes of their own control programs. This leads not only to significant differences in perceived types and quantities of waste that pose hazards to human health and the environment, but also to confusion as to the degree and focus of efforts required to manage hazardous waste.

Waste Generation.—EPA has estimated that 28 million to 54 million tonnes of federally regulated hazardous waste were generated in the United States in 1980. The average value of 41 million tonnes is the amount that is generally quoted. A survey conducted for OTA assembled data on waste generation based on the different definitions of hazardous waste used by States. The survey indicated that approximately 255 million to 275 million tonnes of hazardous waste generated per year are recognized by the States. Much (although not all) of the "extra" waste regulated by States are of relatively low-hazard level, such as mining waste and fly ash. Other wastes which escape the Federal definition and regulation, such as wastes from small quantity generators, pose substantial hazards. These and other wastes currently exempted from control under RCRA by Congress and EPA total several hundred million tonnes per year. They are summarized in table 1. In general, the large-volume exempted wastes are those of lower hazard, although the quantities of high-hazard wastes may be very substantial (the volumes of many of these wastes are unknown). In addition, cleanup actions at uncontrolled sites produce several million tonnes of hazardous waste and contaminated materials annually which must be managed. These have not been included in EPA's estimates.

Generators and Storage, Treatment, and Disposal Facilities.—It is possible to collect accurate data on individual hazardous waste generators, management facilities, and methods of waste disposal. However, the national data base is generally recognized to be incomplete, and in some respects inaccurate, even by EPA. These data must serve as the basis for permitting efforts, and must be progressively updated as that effort proceeds. Most wastes—generally 70 to 85 percent nationwide—are managed on the sites where they are generated. Accurate data on the use of different waste management methods are not available; however, it is clear that on a volume basis most hazardous waste (as much as 80 percent according to early EPA data) are land disposed. Use of land disposal varies among States; for example, in Louisiana about 97 percent of waste managed onsite and 50 percent of those managed offsite are land disposed. In Texas, 95 percent of hazardous waste are land disposed. In Massachusetts, only 7 percent is land disposed, and all of that is sent to other States for disposal.

Uncontrolled Sites.—The CERCLA program has made some progress in identifying the number and location of uncontrolled sites requiring remedial action, particularly for known problem sites. EPA now has a list of more than 15,000 sites, and 418 sites have been selected for the National Priority List. However, the inventory of uncontrolled sites in the Nation is still incomplete, and the severity of the hazards posed by many of the priority sites is uncertain (which is true as well for the thousands of sites not on the priority list). The model used to evaluate hazards has serious inadequacies (see issue 5).

Health and Environmental Effects.—Data on potential health and environmental effects are critically needed for the Federal hazardous waste program as a basis for establishing appropriate levels of regulatory control. The current situation is not satisfactory. There are very few data on the short- and long-term health and environmental effects of exposure to actual hazard-

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*In RCRA, solid waste refers to a general class of wastes that may be solid, liquid, gases, or complex mixtures of a number of phases.

Table 1.—Examples of Exemptions From Federal Regulation as Hazardous Waste

Waste type	Estimated annual generation (million metric tons)	Possible hazard	Determined by
Fly and bottom ash from burning fossil fuels[a]	66	Trace toxic metals	RCRA
Fuels gas emission control waste	Unknown	Toxic organics, and inorganics	RCRA
Mining waste, including radioactive waste[b]	2,100	Toxic metals; acidity; radioactivity	RCRA
Domestic sewage discharged into publicly owned treatment works[b]	5	Uncertain, toxic metals likely	RCRA
Cement kiln dust[a]	12	Alkalinity, toxic metals	RCRA
Gas and oil drilling muds and production waste; geothermal energy waste	Unknown	Alkalinity, toxic metals, toxic organics, salinity	RCRA
NPDES permitted industrial discharge	Unknown	Toxic organics, heavy metals	RCRA
Irrigation return flows	Unknown	Pesticides, fertilizers	RCRA
Waste burned as fuels[c]	19	Unburned toxic organics	EPA
Waste oil	Unknown	Toxic organics, toxic metals	EPA
Infectious waste	Unknown	Infectious materials	EPA
Small volume generators[d]	2.7-4.0	Possibly any hazardous waste	EPA
Agricultural waste	Unknown	Variable	EPA
Waste exempted under delisting petitions†	Unknown	Presumably insignificant†	EPA
Deferred regulations	Unknown	Unknown	EPA
EPA deregulation	Unknown	Presumably insignificant	EPA
Toxicity test exemptions‡	Unknown	Organics	EPA
Recycled waste††	Unknown	Improper application of various materials	EPA

†Wastes may be delisted on the basis of a petition that is concerned only with the constituent(s) which have determined the original listing; however, other hazardous constituents may be present which have previously been unrecognized administratively.

‡Wastes not identified as toxic by the EPA extraction procedure test and not otherwise listed by EPA.

††Legitimate recycling is exempt from RCRA regulations except for storage. However, there have been numerous incidents (e.g., the dioxin case in Missouri) involving recycled materials which are still hazardous.

SOURCES: [a]Federal Register, vol. 43, No. 243, 12/18/78.
[b]"Technical Environmental Impact of Various Approaches for Regulating Small Volume Hazardous Waste Generators" (Washington, D.C.: Environmental Protection Agency, contract No. 68-02-2613, TRW, December 1979).
[c]"A Technical Overview of the Concept of Disposing of Hazardous Wastes in Industrial Boilers" (Cincinnati, Ohio: Environmental Protection Agency, contract No. 68-03-2567, Acurex Corp., October 1981).
[d]"The RCRA Exemption for Small Volume Hazardous Waste Generators, Staff Memorandum" (Washington, D.C.: U.S. Congress, Office of Technology Assessment, July 1982.

ous waste. The considerable scientific data that exist are useful, but the data usually must be extrapolated from animal to human health effects, from high to low concentrations of hazardous constituents, and from exposure to pure chemicals to exposure to complex waste mixtures. The disease registry and health survey required by CERCLA, to provide more data on health effects of hazardous waste, have not been implemented satisfactorily.

Priorities for Data Acquisition.—A major obstacle to assessing the long-term effectiveness of RCRA and CERCLA implementation by EPA and States is inadequate health and environmental effects data. Substantial efforts are needed in this area. Other data priorities include: hazardous waste generators (who and where they are, and their types and quantities of wastes) and management facilities (technology types and capacities); the performance of different kinds of facilities and technologies and degree of risk associated with each; alternative industrial processes for waste and hazard reduction; uncontrolled sites; capital and operating costs of waste management facilities; and regulatory compliance costs.

Institutional Factors.—There is a need for a long-term, systematic EPA plan—for which a congressional mandate does not yet exist—for obtaining more complete and reliable data on hazardous wastes, facilities, sites, and exposures to and effects from releases. The likely consequences of devoting inadequate resources to obtain accurate information include the following:

- Federal and State programs to protect the public from hazardous waste may be inappropriate or misdirected and long-term risks to public health and the environment may not be properly assessed.

- Over time it will be difficult to evaluate the effectiveness of the large funds spent by Federal and State regulatory programs and the private sector.
- Eventual costs of protecting public health and the environment may escalate because wastes, facilities, and sites may not have been properly identified and, therefore, may be receiving either inadequate or excessive attention under RCRA or CERCLA. The costs to provide remedies where waste facilities were omitted from or inadequately managed under present programs will increase markedly over time as sites deteriorate and releases enter the environment.

ISSUE 2

Can the amount of hazardous waste that is generated be further reduced, and does the Federal regulatory program provide incentives or disincentives for waste reduction?

FINDING

Several technological approaches can be used to reduce the amount of waste requiring treatment or disposal. The current Federal program indirectly provides more disincentives than incentives for waste reduction (see ch. 5).

An important way to reduce threats to public health and the environment from hazardous waste and to lessen the cost of waste management is to reduce the amount of waste generated. Generators of waste can accomplish this by segregating waste more carefully or recycling them, or sometimes by changing manufacturing processes or products. Whether they will in fact do so depends on the economic costs and savings involved. The generator's costs are influenced by government regulations. A generator may, for example, recycle a waste even though it adds to his costs, if the cost is less than treating or disposing of the waste in the manner required by government regulations.

Some initiatives undertaken by the private sector indicate that there are opportunities for waste reduction which, in the right circumstances, can lead to economic benefits for the waste generator. First, the cost of changes that reduce waste generation may be more than offset by lower waste management costs. Then, materials or energy recovered from materials before discard or from wastes can in some cases be used or sold for profit. Sometimes, changes in processes motivated by waste management concerns may help introduce innovative new technologies.

Table 2 presents a summary of the advantages and disadvantages of the major approaches to waste reduction. There is considerable evidence based on practical experience that these approaches are technically feasible, to different degrees, for many hazardous wastes. Specific findings concerning the current state of usage of the four major approaches to waste reduction are:

- **Source segregation or separation** is usually the easiest and cheapest method of reducing waste before they require management as hazardous waste. This method has been widely used in industry and offers further opportunities for application. The basic principle is to keep waste in concentrated, isolated forms rather than to form large volume indiscriminate mixtures that must be separated later.
- Hazardous waste reduction by **process modification** is usually a secondary benefit; the changes are motivated by other engineering and economic considerations, such as improving process efficiency and yield. The benefits are usually specific to individual plants and processes. Impacts on hazardous waste reduction industry-wide have been limited.
- **End-product substitution** appears to offer long-term benefits. However, full realization of the benefits depends on its application to many industrial sectors and markets. Changing one product, or one application of a product, is likely to have only a relatively small effect on hazardous waste generation. Here, too, waste reduction is usually a secondary benefit, with product performance improvements being the main driving force for change. However, as hazardous waste management becomes more expensive and costs are

Table 2.—A Comparison of the Four Waste Reduction Methods

Advantages	Disadvantages
Source segregation or separation	
1) Easy to implement; usually low investment	1) Still have some waste to manage
2) Short-term solution	
Process modification	
1) Potentially reduce both hazard and volume	1) Requires R&D effort; capital investment
2) Medium-term solution	2) Usually does not have industrywide impact
3) Potential savings in production costs	
End product substitution	
1) Potentially industrywide impact—large volume, hazard reduction	1) Relatively long-term solutions
	2) Many sectors must be affected to achieve significant benefits
	3) Usually a side benefit of product improvement
	4) May require change in consumer habits
	5) Major investments required—need growing market
Recovery/recycling	
• *In-plant*	
1) Medium-term solution	1) May require capital investment
2) Potential savings in manufacturing costs	2) May not have wide impact
3) Reduced liability compared to commercial recovery or waste exchange	
• *Commercial recovery (offsite)*	
1) No capital investment required for generator	1) Liability not transferred to operator
2) Economy of scale for small waste generators	2) If privately owned, must make profit and return investment
	3) Requires permitting
	4) Some history of poor management
	5) Must establish long-term sources of waste and markets
	6) Requires uniformity in composition
• *Waste exchange*	
1) Transportation costs only	1) Liability not transferred
	2) Requires uniformity in composition of waste
	3) Requires long-term relationships—two-party involvement

SOURCE: Office of Technology Assessment.

passed on to consumers, the awareness of the "hazardous waste-intensiveness" of products may contribute more to end-product substitutions.

- **In-plant recycling** has been widely used in industry for waste reduction. Onsite recycling and recovery can be done before materials are discarded and managed as hazardous waste, thereby reducing the volume and perhaps the hazard level of the waste that are eventually generated. **Commercial or offsite recovery** operations have had varying degrees of success, depending on problems with contamination of waste, consistency of waste composition and supply, and market factors. All these greatly influence profitability. Generally, commercial recovery is more attractive to small- to medium-sized waste generators that do not have the capital for in-plant installations. Waste exchanges have not yet become a major influence because larger generators cannot transfer their liability for the waste (imposed by RCRA) to the waste user, and small generators have too little waste to pay the costs of exchange, or, in some cases, to assure consistent types and volumes to users.

Institutional Factors.—The Federal hazardous waste regulatory structure does not now provide direct incentives for use of any of the approaches mentioned above: segregation of waste components at the source of generation, modifications in manufacturing processes, development of end-product substitutions, and greater use of in-plant and commercial recycling and recovery operations. In part, this is because the emphasis in RCRA is not on reducing waste generation but on management of waste once they are generated, and EPA has not generally pursued the resource recovery aspects of RCRA. Moreover, **a number of current regulatory policies and practices may ac-**

tually act as disincentives for waste reduction and treatment activities. In some instances, process intermediates containing recoverable materials or energy are defined as waste even though they are not discarded. This can act as a disincentive to some recycling.

An important disincentive is the policy of keeping landfill costs low, even under the new RCRA regulations by:

- not requiring comprehensive, stringent monitoring at landfills;
- not requiring retrofitting of existing, active landfills;
- a liberal interpretation of "existing" in exempting, from some of the new regulations, portions of existing landfills that do not yet contain waste;
- limiting post-closure monitoring requirements to 30 years; and
- not requiring location of waste management facilities to protect drinking water sources.

As discussed further in the next section, the defects of the land disposal method may be postponing cleanup costs to the future, and it is likely that these costs will be borne by government or society in general. Externalizing such costs away from the private market to the public sector provides an indirect incentive for land disposal. Nevertheless, to a limited extent, for some waste generators, increasing costs under the current program and the perceived liabilities of land disposal are indirectly promoting more use of waste reduction methods.

A common question is: How much of the Nation's hazardous waste could be eliminated by the various approaches to waste reduction? Any estimate of what could be done technically and economically can be only a crude approximation. Theoretically, the generation of almost every hazardous waste might be affected to some extent by one or more of the approaches discussed previously. A 1981 California study of future hazardous waste generation concluded that new industrial plants will produce only half the amount of hazardous waste currently produced. Other estimates for potential waste reduction range from 30 to 80 percent. Waste reduction efforts, however, are more difficult to make in existing plants than in new ones. In addition to regulatory factors, capital and R&D needs—particularly for smaller hazardous waste generators—are important obstacles to implementing waste reduction efforts. General economic and market factors play a crucial role in raising and committing capital.

ISSUE 3

Are alternatives to land or ocean disposal of wastes available and used? How do Federal regulatory programs affect their use? Are concerns about the risks of land disposal of hazardous waste well founded?

FINDING

Not all of the technically feasible management options for hazardous waste are being used to their full potential. On the whole, Federal programs indirectly provide more incentive for disposal options than for alternatives. Land disposal, even if in compliance with RCRA, probably poses some preventable risks both in the near term and for the future. But land disposal is appropriate and necessary for many wastes (see chs. 5 and 7).

Management Alternatives.—Once hazardous waste are generated, they can be managed by one of two broad categories of technologies:

1. treatment by one or more steps to reduce the hazard level of the waste, or
2. disposal through containment or dispersal on land or in the oceans.

Treatment technologies reduce the hazard level directly or facilitate reduction in other steps by changing the physical or chemical nature of the waste, by separating waste constituents, by reducing the waste volume, or by reducing the concentration of hazardous substances in the waste. The treatment technologies include chemical, thermal, and biological treatments.

Containment technologies hold waste in a manner intended to inhibit release of hazardous components into the environment or keep releases to acceptable levels. These technologies include landfills, surface impoundments, and underground injection wells. With most containment options, it is probable that releases will occur at some time. Some surface impoundments are designed, in fact, to transfer material to the ground. Dispersal techniques, such as land treatment (spreading waste on the land) or ocean dumping, rely on naturally occurring processes to reduce the hazard level of waste constituents, or to transport them into and through the environment thereby diluting concentrations to acceptable levels, or both. Some geographical locations are generally understood to make exceptionally good sites for land disposal facilities because their hydrogeological characteristics make releases unlikely and because the probability that people or sensitive elements of the environment would be exposed to releases is extremely low.

The degree of feasibility and appropriateness of a specific management technology for a specific waste depends on many factors, including the characteristics of the waste and the environmental features of the facility site. Regulatory requirements and the goals and economic calculations of waste generators and handlers will also influence technology choices. A summary comparison of the major waste management alternatives (hazard reduction through treatment or disposal) is given in table 3.

Technology Selection and Waste Type.—Waste type is an important determinant of the technology chosen for waste management. For example, some wastes are technically incompatible with a specific technology because they would damage equipment. For wastes characterized as hazardous because of their reactivity, corrosiveness, and ignitability, there are well-established chemical and physical treatments available. However, for a waste in which toxicity is the major hazardous characteristic, the choices are not clear. Toxic constituents may be organic, inorganic, or metallic, and many technologies could be used. The major issue is whether to use a treatment or containment approach. For the most toxic waste, the preferred choice is treatment when it is technically feasible.

In general, the kinds of waste most suitable for land-based containment are residuals from treatment operations, pretreated (or stabilized) waste, untreatable waste, and relatively low-hazard (and often high-volume) waste. However, some untreatable waste are so highly toxic that land disposal should not be used, and waste elimination is the only acceptable alternative (exemplified by the statutory prohibition on the use of polychlorinated biphenyls (PCBs). Appropriate use of the

Table 3.—Comparison of Some Hazard Reduction Technologies

	Disposal		Treatment		
	Landfills and impoundments	Injection wells	Incineration and other thermal destruction	Emerging high-temperature decomposition[a]	Chemical stabilization
Effectiveness: How well it contains or destroys hazardous characteristics	Low for volatiles, questionable for liquids; based on lab and field tests	High, based on theory, but limited field data available	High, based on field tests, except little data on specific constituents	Very high, commercial-scale tests	High for many metals, based on lab tests
Reliability issues:	Siting, construction, and operation Uncertainities: long-term integrity of cells and cover, liner life less than life of toxic waste	Site history and geology; well depth, construction and operation	Monitoring uncertainties with respect to high degree of DRE; surrogate measures, PICs, incinerability[c]	Limited experience Mobile units; onsite treatment avoids hauling risks Operational simplicity	Some inorganics still soluble Uncertain leachate test, surrogate for weathering
Environmental media most affected	Surface and ground water	Surface and ground water	Air	Air	Ground water
Least compatible wastes:[b]	Liner reactive; highly toxic, mobile, persistent, and bioaccumulative	Reactive; corrosive; highly toxic, mobile, and persistent	Highly toxic and refractory organics, high heavy metals concentration	Some inorganics	Organics
Costs: Low, Mod, High	L-M	L	M-H (Coincin. = L)	M-H	M
Resource recovery: potential	None	None	Energy and some acids	Energy and some metals	Possible building material

[a] Molten salt, high-temperature fluid wall, and plasma arc treatments.
[b] Wastes for which this method may be less effective for reducing exposure, relative to other technologies. Wastes listed do not necessarily denote common usage.
[c] DRE = destruction and removal efficiency. PIC = product of incomplete combustion.

SOURCE: Office of Technology Assessment.

oceans for disposal has not been resolved. For **some** hazardous waste, dumping in **certain** ocean locations appears to offer acceptable levels of risk for both the ocean environment and human health. However, there is generally inadequate scientific information to decide what the locations are for specific wastes.

Comparisons of Technologies.—Several technical factors make it difficult to compare treatment and disposal alternatives (see table 3). The goal for each technology is to reduce the probability of release of hazardous constituents, but no technology can offer zero release. Performance capabilities for different technologies must be considered in relative terms; releases that do occur vary in location, quantity, and time. For example, landfills inhibit releases through containment but will eventually (and usually gradually) leak and may contaminate ground water. Incinerators destroy most of the waste, but some air pollution will occur. Stabilization of waste immobilizes hazardous constituents but often allows some hazardous constituents to be dissolved (leached), albeit at slow rates. Chemical treatment, such as dechlorination, detoxifies but may produce some residue requiring disposal. An important issue in making comparisons, and for regulatory purposes, is to describe the nature and impact of potential releases, not merely what the technology accomplishes. For example, a technology may destroy or detoxify 99.99 percent of a waste constituent input, but it is necessary to consider the total amounts released and their toxic effects.

Another factor influencing comparisons is that different technologies achieve their objective with differing efficiencies, such as degree of destruction, degree of containment, and degree of stabilization. Another factor to consider is the variation in potential routes of releases, such as air for incinerators and ground water for landfills. These are important qualitative differences that influence the character of risks. The reliability of different technologies is also important. Reliability depends, for example, on the degree of direct process control available, the effectiveness and accuracy of surrogate (indirect) process monitoring measures, and the opportunity to correct emissions prior to environmental discharge. Finally, opportunities for energy and material recovery vary among alternative technologies.

Comparison of Direct Costs.—Costs are generally considered on some volume or weight basis for a particular management technique. It is not possible at present to compare costs of treatment and disposal alternatives on the basis of **comparable levels of control** because:

1. consensus is lacking about what constitutes comparable levels of control across technologies;
2. there are regulatory uncertainties in the evolving Federal program;
3. cost data are specific to applications, locations, and wastes; and
4. costs are changing as generators find lower cost alternatives in response to regulatory and market conditions.

An important conclusion, however, is: **even though RCRA regulations will increase land disposal costs, land disposal is still likely to be the low-cost option under the current regulations for most hazardous waste.** In addition, costs for treatment technologies are more sensitive to waste type than are land disposal options.

Table 4 summarizes direct costs for commercial, offsite treatment, and disposal alternatives on a per tonne basis (as received wet or dry). Generally, different technologies compete at the low end and in the middle of the price spectrum, but in some cases the exact character of the waste, not the cost, determines the applicability of different technologies and therefore the management choice. There are greater price differences among the technologies for managing the most hazardous waste, with incineration markedly more costly than land disposal, and some chemical treatments being as costly as incineration.

It should be noted that transportation costs to waste management facilities can be quite substantial, with long distances increasing direct costs by as much as 50 to 100 percent. In some locations, there may be no nearby

Table 4.—Representative Unit Costs for Commercial Hazardous Waste Treatment and Disposal

Category	$/tonne
Typical ranges:	
Land disposal	
Landfills (low to high hazard drummed waste)	$13-$240
Deep well injection—oily waste waters	$16-$40
Land treatment, farming or spreading	$5-$24
Chemical treatment—acids or alkalines	$21-$92
Incineration (clean combustible liquids to highly toxic and refractory solids or drummed waste)	$53-$800
Most costly:	
Landfills (extremely hazardous waste)	$168-$240
Deep well injection—toxic rinse waters	$132-$264
Chemical treatment—cyanides, toxic metals, highly toxic wastes	$66-$791
Incineration (solid or drummed highly toxic waste)	$400-$800

SOURCE: Office of Technology Assessment, based on various published sources.

alternatives to land disposal, and the added cost for transportation makes land disposal even more attractive economically. Also, the smaller the quantity of waste handled, the greater the per-unit treatment or disposal costs. There are, however, new commercial enterprises aimed particularly at the small generator market. Various techniques can be used to reduce handling costs, including using trucks that deliver chemical feedstocks to pick up carefully labeled and separated hazardous waste.

Land Disposal Risks.—All treatment and disposal options for hazardous waste inescapably pose some risks to public health and the environment. Technical experts and the public are concerned because land disposal facilities can release hazardous constituents at some indeterminate time in the future. Although the likelihood of **some** releases is high, there are considerable uncertainties about:

1. the likely quantity and timing of releases of particular constituents,
2. the rates of transport of released hazardous constituents through the environment and their rates of degradation in the environment,
3. the extent of possible exposures of people and the environment to persistent hazardous constituents and their degradation products, and
4. the probability of damages.

The uncertainty of the risks, the fact that people are unable to control their own exposure to the risks, the as yet unproven ability of RCRA regulations to detect or minimize releases, and the uncertainties about effective cleanup of old waste dumps that are a legacy of **past** land disposal practices all contribute to a widespread belief by technical experts and the public that land disposal of many types of waste poses unacceptable risks. As with most public debates over perceived risky situations, it is not only the technical aspects of the risk that matter. In addition, public perceptions of the risk levels and their acceptability influence priorities. In the case of land disposal, the issue appears to be when and how, rather than if the use of land disposal is to be reduced.

Use of Land Disposal v. Its Alternatives.—Available information indicates that **land-based disposal methods are used for most wastes (as much as 80 percent according to early EPA data, see issue 1), including many that are treatable or recyclable.** There is insufficient information to determine exactly the extent to which land disposal options may be used nationwide for waste that could be treated or recycled.

In 1981, a study on California waste managed offsite concluded that:

1. 75 percent of the hazardous waste disposed in landfills (classified as the most secure by the State) could be recycled, treated, or destroyed,
2. almost 40 percent of all land disposed hazardous waste were highly toxic and very persistent,
3. most of the additional waste management capacity needed to recycle, treat, or destroy hazardous waste could be developed in less then 2 years; and
4. the additional cost of recycling, treating, or incinerating highly toxic waste would have a minimal effect on industry.

Nationally, a recent study for EPA of nine major commercial waste management companies showed that capacity utilization for incineration in recent years was about 80 percent, for chemical treatment just over 50 percent, and for recycling it was 24 percent. These data indicate that available capacity for offsite management of wastes is not a barrier to shifting management choices away from land disposal.

Even more technological alternatives to traditional land disposal could be developed in the years ahead. Only about 10 percent of EPA's current R&D efforts for hazardous waste are devoted to alternatives to land disposal. Emerging thermal, physical, and chemical treatment technologies are at a point where they could substantially benefit from more R&D support. Certain physical/chemical processes now being developed offer unusual benefits with regard to preventing emissions of hazardous constituents, providing resource recovery, and reducing toxicity.

Institutional Factors.—The current regulatory structure does not directly encourage consideration of alternative, safer, and more permanent solutions to problems posed by the very complex nature of hazardous waste. Indirectly, the increased stringency of RCRA regulations for land disposal facilities, increased emphasis on financial liability and future legal actions, increased public concerns, and increasing costs for land disposal have all contributed to greater consideration of treatment alternatives to disposal where they are technically feasible.

The current Federal program, however, also presents indirect, and probably inadvertent, disincentives for treatment alternatives to disposal. The following recent statement by EPA's senior official for hazardous waste regulation signals the continuing acceptance of land disposal options:

> We believe that most wastes can be satisfactorily managed in the land and that it can be done with a reasonable margin of safety more cheaply in this manner. . . . it may be that recycling or destruction is preferable from a strictly health and environmental protection standpoint, but for many wastes, the reduction in risk achieved is probably marginal and may not be worth the cost."[6]

However, EPA has made technical statements of a more cautious nature about disposal: ". . . the regulation of hazardous waste land disposal must proceed from the assumption that migration of hazardous wastes and their constituents and by-products from a land disposal facility will inevitably occur."[7] In the final land disposal regulations where stringency depends, in part, on the use of liners beneath wastes, EPA has also said ". . . any liner will begin to leak eventually."[8] The regulations also state that a landfill liner must completely "prevent" migration during the active life of a landfill, and that it must "minimize" migration thereafter. There are substantial differences of opinion in interpreting what these requirements mean, and how to implement them technically. Concerns over who will pay for actions necessary to deal with expected and unexpected releases of hazardous constituents are heightened by the absence of any financial responsibility requirements for the operator to take corrective action if there are releases of hazardous constituents from land disposal facilities. There are, however, RCRA closure and post-closure financial responsibility requirements, and a CERCLA Post-Closure Liability Trust Fund, but there are uncertainties about the long-term effectiveness of these approaches. The net effect is that current RCRA regulatory policies continue to make land disposal attractive economically, despite uncertainties over long-term safety, although much less so than before these regulations. Thus, long-term risks and costs, to some extent, are transferred to government or society in general. Without the full internalization of costs, land disposal options retain a competitive advantage against treatment alternatives and, therefore, an indirect disincentive for such alternatives exists.

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[6] Testimony of Rita M. Lavelle, Assistant Administrator for Solid Waste and Emergency Response, EPA, U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Natural Resources, Agriculture Research and Environment, Dec. 16, 1982.

[7] Federal Register, vol. 46, No. 24, Feb. 5, 1981.

[8] Federal Register, vol. 47, No. 143, July 26, 1982.

Until the private sector perceives the regulatory structure as not containing a bias in favor of land disposal technologies, investment in new treatment technology R&D and commercial development may be limited. Equally important are the size and certainty of the total waste management market, which is also dependent on Federal hazardous waste policies, particularly those concerning the universe of waste regulated. The use of direct Federal incentives for alternatives to land disposal has not been pursued by EPA thus far. EPA has, however, commented favorably on the use by some States of tax and fee systems that can raise revenues to offset a loss in Federal grants that support State hazardous waste control programs. In some cases, the State tax and fee systems are structured to promote alternatives to land disposal.

ISSUE 4

Can the various kinds of hazardous waste be differentiated by estimates of hazard potential? Could waste and facility classification play a useful role in the regulation of hazardous waste?

FINDING

Waste can be differentiated into at least three categories of hazard. Waste classes can be combined with facility classes to form a technical base for Federal regulatory policies. Developing the details of waste and facility classification would require substantial work (see ch. 6).

Hazard classification models are available that differentiate among the variety of industrial waste based on measures of potential hazard posed to human health or to the environment. Criteria used to rank hazards differ. Some models use only measures of acute toxicity and carcinogenicity. Some consider toxicological criteria and estimate environmental fate of waste constituents. Others include safety factors, toxicity measures, and concentration levels for major constituents. Although each model has drawbacks, a case study performed for OTA of selected RCRA waste treated by EPA regulations as equally hazardous, indicates that **waste can be differentiated into at least three categories of hazard.**

Certain problems, however, emerge in the attempt to classify wastes:

1. criteria must be chosen carefully to maximize protection of public health and the environment, and to identify sensitive species which may be exposed;
2. ranges of measurements must be used that reflect expected doses and exposures; and
3. incomplete data bases, including problems of variability and interpretation, can hamper classification of some wastes.

Classification of any particular waste can vary depending on the system used; the choice and weighting of technical criteria are critical. Concerns over the determination of boundaries for classes should be addressed by developing technical justifications and working for a consensus among industry, government, the scientific community, and public interest groups.

Classification of wastes can be combined with facility classification to serve as the technical basis for a regulatory program. Facility classes would distinguish among different designs of a particular type of facility and among different physical locations. The risk potential of a facility depends on the environment surrounding the facility, meteorological conditions, the impact of facility operation on the waste (e.g., treatment or containment), and the technological limitations of facility design and operating conditions. For example, two or three classes of incinerators could be developed with different destruction and removal efficiencies. Several landfill classes might be formulated relating permeability potential of liners to the environmental conditions of a site such that wastes would be contained for specified periods. Different facility classes would require different types and levels of monitoring.

Waste and facility classes must be matched so that consistent risk levels are obtained across both waste and facility classes. For example, the risk from a waste class I and facility class I combination should be substantially the same as from a waste class II and facility class II combination.

Although there are technical limitations that must be recognized, the use of classification systems for wastes and facilities offers certain advantages over the current regulatory program.

ISSUE 5

To what extent can risk assessment be used in the regulation and management of hazardous waste?

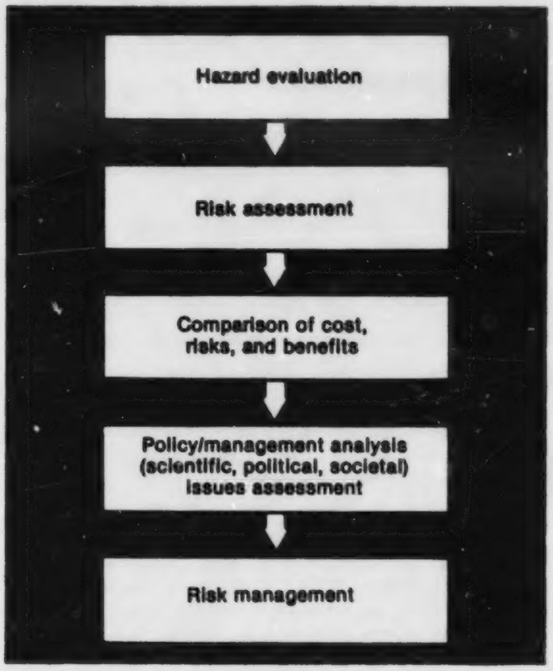
FINDING

The technical limitations of risk models, assumptions, and data require careful attention. However, risk assessment has a useful role as an analytical tool in the total risk management and decisionmaking framework (see chs. 6 and 7).

Risk assessment involves two steps: risk estimation and validation of the estimate (too often omitted or deemphasized). Risk estimates are based on evaluations of the hazard potential of wastes and identification of relationships between the potential hazard and health and environmental effects. In some instances, risk estimation is calculated using mathematical models to extrapolate from high doses, used in laboratory situations, to low doses, which may be detected in the environment. **Individual estimates generated by different models can vary considerably, even when the same data are used.**

Risk assessment can assist in making a variety of decisions, including establishing regulatory standards, setting priorities for R&D, identifying risk levels associated with treatment and disposal options, and determining appropriate locations for waste management facilities. But risk assessment is only one component in a risk management framework, as shown in figure 1. Several models are available for analyzing tradeoffs between costs, risks, and benefits. It should be emphasized, however, that RCRA precludes balancing costs and risks. **Risk assessment is best regarded as an analytical tool and not as the final decision process.** Decisionmakers evaluate the results of risk assessments in the context of many nonquantitative factors, including all the uncertainties of the risk analysis, value judgments made in the assessment, special interests that have been recognized (or not), and sociopolitical factors of importance to the issue. In risk management, conflicts among these factors always will exist. Such conflicts represent differences in societal interests and perspectives and, thus, must be considered in the decisionmaking process.

Figure 1.—Risk Management Framework


Hazard evaluation
Risk assessment
Comparison of cost, risks, and benefits
Policy/management analysis (scientific, political, societal) issues assessment
Risk management

SOURCE: Office of Technology Assessment.

Because better data and information are critical to risk management decisions, it is often implied that tradeoffs must be made between expeditious protection of the public and the need to obtain improved data. However, considerable data exist to allow some reasonable risk assessments to be made, bearing in mind the previously noted limitations. RCRA requires protection of the public from hazardous waste in the near term on the basis of known (or presumed) toxic and other harmful substances in such waste, and on the basis of documented adverse incidents. **A scientifically certain link between disposal of hazardous waste at a specific location and resulting health or environmental effects, particularly long-term ones, is usually not possible.**

Recently, EPA developed two risk assessment models for CERCLA and RCRA applications. While the concept of using risk models for regulatory purposes has merit, the assumptions used by EPA as the basis for these particular models are so simplistic that their usefulness is questionable. For example, both models incorporate a concept that can result in unequal protection of some segments of the public. In these models, estimates of risk depend on population density close to the site. Areas of low population density will receive lower risk estimates than areas with high population densities, but this is not necessarily as sensible as it first appears. **Actual risks depend on where and how releases of hazardous constituents move through the environment, the ultimate fate of the materials, and, most importantly, the doses or exposures received by particular people or elements of the environment.** Population density by itself is a poor indicator of actual individual exposures and risks (i.e., "per capita risk"), and risks may be high or low, independent of overall population density. In addition to the problems in the way population density is used, there are problems in these models with the criteria used to determine hazard potential. These and other problems lead to considerable uncertainty in the final risk estimates.

ISSUE 6

What contribution can monitoring make to effective risk management and is such a contribution required by the current RCRA program?

FINDING

Current monitoring practices and requirements under RCRA do not lead to a high level of confidence that releases will be detected and responsive action quickly taken (see chs. 6 and 7).

Monitoring can generate data to serve as a technical basis for regulatory action and as verification that public health and the environment are being protected. There are several closely related functions for monitoring: establishing baseline or background data, developing data for setting regulatory standards, verifying compliance with regulations, identifying R&D priorities, and assessing contamination.

Two different monitoring strategies can provide information about the operation of hazardous waste management facilities. Surveillance monitoring can verify compliance with regulatory requirements and provides limited data about changes in environmental quality. Assessment monitoring is used to determine the extent of deterioration in environmental quality and also provides data that indicate cause-effect relationships for specific hazards. Regulatory programs should employ both strategies—with surveillance monitoring required for all facilities, and assessment monitoring used when the results of the former indicate an emerging problem.

Both monitoring strategies pose problems including sampling procedures, data comparability, and limitations in available analytical methodologies. For example, difficult choices must be made regarding the location and number of sampling sites and the frequency with which samples are taken. A poor choice of sampling location could miss the detection of "hot spots" of contamination. Data comparability is possible only if standardized sampling and analytical protocols are used. Variances can occur among results if different laboratories and equipment are used, and even if different personnel perform the same test. Greater attention should be given to these "practical" aspects of the national hazardous waste monitoring program and to the development of an adequate analytical infrastructure nationwide.

Of the five types of monitoring (visual, process, source, ambient, and effects), only visual, process, and source are incorporated into RCRA regulations to any significant degree. Limited ambient monitoring is required of land disposal facilities but collection of effects data is not required. If effectively conducted, visual, process, and source monitoring can reduce the amount of ambient monitoring that may be needed by minimizing the release of hazardous constituents into the environment. However, they cannot serve as a substitute for ambient monitoring.

Ambient monitoring provides information on the appearance of statistically significant levels of contaminants in air, soil, water, and biota. **Ambient monitoring holds the greatest potential for minimizing risks that might result from hazardous waste mismanagement.** Only by taking representative samples from potentially affected locations and environmental media and then analyzing them for a broad spectrum of potential contaminants is it possible to control risks reliably. **Minimization of releases of hazardous constituents ultimately provides the greatest protection of public health.** Furthermore, environmental media, and the processes that influence the movement and fate of hazardous releases, are protective barriers against human exposure. If contamination of air, water, or land can be detected sufficiently early (before widespread contamination and actual damage) and corrective action taken, then human exposure will be reduced. **Ambient monitoring, therefore, should be given a greater role in the RCRA regulatory program.**

The full potential of monitoring is not required by the RCRA regulations. Specific but limited monitoring activities are required only for incinerators and land disposal facilities. Land disposal facilities are required to conduct limited ambient monitoring (i.e., four samples taken twice a year). However, there are exemptions to ground water monitoring requirements for land disposal facilities that have a double liner and a leak detection system between the liners. This could lead to delays in detecting the release of contaminants. Furthermore, even if ambient monitoring is conducted, EPA's guidelines for locating sampling wells will not provide adequate representations of the quality of an aquifer in all cases because of the possibility of complex aquifer shapes and flows. Contamination limits established for ground water protection for land disposal facilities have serious inadequacies.

With regard to discharges to air and water, waste treatment facilities must comply only with monitoring requirements of the Clean Air and Clean Water Acts. Because these acts do not cover the broad range of hazardous constituents that are of concern in RCRA, reliance solely on monitoring required by the Clean Air and Clean Water Acts appears risky.

There are also serious concerns over the possible lack of routine reporting of monitoring data obtained by facility operators to, and verification by, State programs, and accessibility of monitoring information to the general public. Therefore, **limited monitoring requirements established for treatment, incinerator, and land disposal facilities will not likely provide adequate protection of either public health or the environment, particularly over the long term.**

ISSUE 7

How effectively is CERCLA addressing the problem of uncontrolled hazardous waste sites?

FINDING

Some progress is being made toward cleaning up some of the worst uncontrolled sites. However, many sites will not have received attention when collection of the CERCLA tax expires in 1985. There is still incomplete information on the long-term effectiveness of cleanup techniques (see chs. 5 and 7).

Uncontrolled sites may be either operational, inactive, or abandoned. A recent survey of 348 uncontrolled sites, which have received some remedial action, indicated that various types of land disposal techniques were used originally in 97 percent of the cases. There is no question that uncontrolled sites are a large problem for the Nation. EPA's inventory now contains more than 15,000 sites and the total is increasing steadily. Costs of remediation vary greatly, from several hundred thousand to ten to twenty million dollars per site. Through fiscal year 1982 only $88 million of $452 million collected under CERCLA had been spent for cleanups, no cleanup funds had been allocated or expended on 97 of the initial 160 priority sites determined by EPA, and only three sites had been totally cleaned up (one entirely with State funds). The first complete National Priority List contained 418 sites. But the model used to rank sites according to their hazards has important inadequacies (see issue 5).

A major problem is that the National Contingency Plan does not provide specific standards, such as concentration limits for certain

toxic substances, to establish the extent of cleanup. Consequently, there is little assurance that cleanups provide protection of health and environment over the long term. However, another perspective is that flexibility and site-specific standards are both appropriate and effective.

Although the approach being used stresses cost effectiveness, there has not been time for a history of effectiveness to accumulate. Thus, it is not yet possible to quantify and compare technologies. The long-term effectiveness of remedial technologies is uncertain because many remedial technologies are containment approaches and these require long-term operation and maintenance.

Technical approaches for remedial control consist either of actions on the waste, such as drum and contaminant removal, contaminant treatment, and incineration; or of actions on the route of release, such as ground water pumping, encapsulation, and gas control. In recent remedial actions, removal of wastes and contaminants (e.g., soil) accounted for about 40 percent of the cases. Usually, removed materials are land disposed, and are beginning to constitute a significant added management burden in RCRA facilities.

There will be many uncontrolled hazardous waste sites requiring attention when collection under Superfund expires in 1985, perhaps even more than when it was enacted because:

1. not all of the 418 priority sites will be cleaned up; EPA has indicated that perhaps half will be totally cleaned up;
2. the national inventory of uncontrolled sites is as yet incomplete;
3. active sites will continue to be closed under circumstances that may shift cleanup responsibility to CERCLA, and this process may be accelerated by final RCRA regulations and the difficulty of compliance by some facilities;
4. a potentially large number of sanitary landfill (subtitle D) facilities for solid, nonhazardous waste may be closed, and may be contaminated by hazardous waste received in the past and currently (e.g., because of the small generator exemption, exempted recycling facilities, and from household discards of hazardous materials);
5. some States may be unable to provide their matching share for cleanup of sites (10 percent for private sites and 50 percent for government-owned sites); this has already prevented about one-third of the original 160 priority sites from receiving remedial action;
6. States and private parties will have difficulty in securing sufficient funds to clean up sites not selected early in the Superfund program, and these may become more hazardous over time;
7. the lifetimes and performance levels of remediation technologies (particularly containment systems) under either RCRA or CERCLA are limited;
8. corporate financial responsibility for some closed RCRA sites will expire; and
9. "ancient" sites not yet documented will continue to be unearthed (often accidentally) and identified.

ISSUE 8

To what extent can technical means be used to address public opposition to siting of hazardous waste facilities?

FINDING

Improving the scope, quality, and dissemination of technical information and using technical siting criteria could prove useful; however, nontechnical institutional remedies that improve public confidence in government programs may be more effective (see ch. 6).

A paradox exists wherein the same public that calls for safer hazardous waste management frequently opposes the siting of specific hazardous waste facilities. The public generally views risks associated with a specific facility as unacceptable at worst, and uncertain and out of its control at best. Risks and potential damages (direct effects resulting from releases of hazardous constituents, as well as indirect effects resulting from potential problems, such as losses in property values) are borne largely by local communities. There is usually little prospect of timely compensation. In contrast, benefits associated with the myriad of activities that generate hazardous waste are more equally distributed over society as a whole. Furthermore, perceptions of **future** risks are shaped almost entirely by the public's understanding of health and environmental effects from **past** hazardous waste management practices and failures. The public remembers problems with uncontrolled sites and risks from transportation accidents and spills of hazardous material rather than of hazardous waste. **A key issue is the degree of public confidence in new government programs to control hazardous waste, and in contemporary, improved management approaches.** Whatever the causes, continued public opposition poses a substantial obstacle to siting hazardous waste management capacity of any type. The uncertainties and costs related to public opposition make private sector commitments of capital difficult.

Both technical and institutional approaches can be used to address public concerns, but these concerns will never completely be eliminated. In the technical area, public confidence and understanding can be increased by:

1. improving the quality of information disseminated to the public to better describe facility needs, uses, characteristics, and risks;
2. using siting processes based on sound technical criteria to ensure that specific locations have been chosen to reduce present and future risks as well as to satisfy waste generator and management needs; and
3. increasing efforts to promote the development and use of alternatives to land disposal.

However, nontechnical or institutional approaches, mostly at the State level, may be more effective. These include:

1. measures to ensure meaningful and effective public participation in siting and permitting of facilities;
2. programs to provide assurance that in the event of any release of hazardous constituents there will be quick and effective emergency and remedial actions;
3. programs to provide assurance that in the event of damages to health or the environment, or indirect economic effects, injured parties will be able to obtain equitable compensation expeditiously; and
4. programs that provide assurance of continued compliance with stringent regulatory requirements, particularly for monitoring.

Currently, there is little direct Federal involvement in facility siting, other than the permitting of facilities. However, there are a number of possibilities being discussed for greater Federal involvement, including:

- providing technical siting criteria either as a model for States to consider, or as mandatory;
- providing assessment of hydrogeological characteristics of importance in deciding the acceptability of sites;
- providing technical assistance to States, local governments, and the public;
- providing information exchange programs;
- assisting in formal or informal mediation of siting disputes;
- providing use of Federal lands;
- legislative sanctioning of interstate hazardous waste management compacts to ensure adequate hazardous waste management capacity in a regional context; and
- mandating that States engage in hazardous waste planning, based on a hierarchy of waste management alternatives, and then provide adequate management capacity for all waste generated in their States.

Whatever actions are taken to address public opposition to hazardous waste facilities, there is little likelihood of any "quick fixes." Current difficulties with the economy may, in some instances, alleviate public concerns by, for example, making waste management activities more attractive as sources of employment, or as a means to keep or attract industrial plants. However, dampened public concern caused by a depressed economy should not be relied on as a widespread or lasting solution to siting problems. In the longer term, successful experience with the RCRA and CERCLA programs could improve public confidence substantially, but lack of success would cause further erosion in public confidence. The potential loss of Federal funding of State programs, which EPA is discussing, and uncertainties over alternate sources of money will likely exacerbate public concerns.

ISSUE 9

Is the congressional intent that the States become partners in implementing the Federal hazardous waste program being met?

FINDING

The States are being given increasing responsibilities by the Federal program without matching technical and financial resources (see ch. 7).

An important element of the congressional mandate to regulate hazardous waste was the eventual shifting of administration of the programs to the States. The States have had difficulties because the Federal program has experienced changes in direction and delays, and is still incomplete. Nevertheless, it is generally accepted that RCRA has greatly improved the number and quality of effective State hazardous waste programs, few of which existed before RCRA.

However, an element of confrontation has developed between the Federal program and the States. **At a critical time when the program is just beginning to be fully implemented, some States believe that there are substantial impediments to providing adequate protection to the public. In fact, some States may refuse the responsibility of taking over administration of the RCRA program.**

1. States are not receiving increases in financial assistance from the Federal Government corresponding to increased responsibilities for implementing the RCRA program; EPA has indicated its desire to eliminate RCRA grants to the States altogether; and States face uncertainties and delays in attempts to obtain alternative sources of funds.
2. Many States do not have an adequate technical information base or enough technically skilled personnel to carry out their regulatory responsibilities. Data obtained by EPA have often been incomplete, and the level of detail has sometimes been inadequate for use by the States to implement Federal regulations; this has resulted because of statistical sampling rather than total inventory approaches to collecting data. States are hampered in their efforts to obtain necessary information by a lack of funds and a lack of certainty concerning the RCRA regulations. Moreover, a number of RCRA and CERCLA regulations transfer considerable technical standard-setting and decisionmaking to the permit writing stage. However, the complex technical requirements of these areas are substantial, as in hydrogeology, and there may be shortages of State personnel to adequately perform these required functions.
3. Many State officials feel that States are not being given sufficient opportunities to influence the formulation of Federal regulations and policies that they are expected to adopt and implement.
4. States do not have policy guidance or support for regional approaches to dealing with hazardous waste problems.
5. States are not being given sufficient latitude by EPA to develop their own programs that might deviate from the Federal program but lead to the same result—i.e., programs that are consistent with and equivalent to the Federal program in terms of protection of public health and the environment, but are not identical to it in terms of the language in regulations and statutes.
6. In some cases, EPA policies concerning hazardous waste have shifted burdens to the States in the area of solid waste (under Subtitle D of RCRA). At the same time, however, Federal funds for support of State solid waste activities have been

eliminated. Such is the case when wastes that are hazardous are granted exemptions (e.g., from small generators) under subtitle C and can be disposed of in subtitle D sanitary landfills.

7. Problems associated with CERCLA (Superfund) implementation are substantial. States must provide substantial matching funds (10 percent for privately owned sites and 50 percent or more for State or municipally owned sites) to obtain Federal assistance for remedial actions at uncontrolled sites, as well as assuring all future operating and maintenance costs. They must also perform a number of activities, such as assessments of potential Superfund sites and enforcement activities, for which no continued CERCLA funding is available. Hence, many States have found it necessary to use funds from Federal RCRA subtitle C grants for Superfund activities at a time when activities under RCRA are mounting.

One important area of development at the State level are policies and programs to supplement regulation of facilities such as greater use of insurance requirements, civil liability, taxes and tax incentives, and negotiated agreements for dealing with problems posed by hazardous waste. Such means have some potential to improve the overall effectiveness of State and Federal waste programs. In many cases, the major motivation for the use of fee and tax systems is to increase revenues for State hazardous waste programs (or in some instances for general purposes), and secondarily to provide incentives for waste reduction and treatment alternatives to land disposal. States' use of these approaches are not generally in conflict with EPA regulations or RCRA. EPA's State authorization program has generally not focused on State nonregulatory initiatives that could supplement the Federal program, or on efforts to develop acceptable alternative regulatory approaches such as State degree-of-hazard systems.

Policy Options

The current Federal hazardous waste program presents a dilemma. On the one hand, there is a sense of urgency and impatience, derived from 6 years of difficulties in dealing with an extremely broad and complex area of threats to public health and the environment. Suggesting changes in Federal policies, therefore, creates concerns over the possibility of still more delays and uncertainties. Those who support the current Federal program (both RCRA and CERCLA) believe there is a need to allow more time before conclusions concerning effectiveness are drawn and possibly disruptive changes are made.

On the other hand, there is also a widespread belief that current policies and programs could be technically, economically, and socially more effective. Waiting for the determination of the current program's effectiveness, it is argued, may lead to the development of outright crises, such as widespread ground water contamination. There is consensus that we are now acting more effectively than in the past to protect the public from improper management of hazardous waste. But there is also considerable evidence (concerning, e.g., the technical limitations and uncertainties of land disposal techniques) that we may be acting in ways which:

1. are too temporary in nature;
2. may lead to greater risks to the public in the future; and
3. may increase ultimate costs to industry, government, and the public.

Furthermore, this dilemma must be considered in the context of reduced allocations for government programs. Such conditions may prompt industry, State and Federal Governments, and the general public to avoid additional near-term costs associated with a cleaner environment in order to cope with immediate economic difficulties. Thus, options that defer costs, that do not jeopardize current industrial activities, that shift risks to the future may appear more attractive than in the past. Such tradeoffs pose formidable choices for policymakers, made more difficult by current uncertainties concerning the degrees of effectiveness of laws and programs not yet fully implemented.

Five policy options are evaluated in terms of overall goals:

- Option I: **Continuation of the Current Program.**
- Option II: **A More Comprehensive and Nationally Consistent RCRA Program.**
- Option III: **Use of Economic Incentives for Alternatives to Disposal or Dispersal of Hazardous Waste.**
- Option IV: **Development and Potential Use of a Hazard Classification Framework.**
- Option V: **Planning for Greater Integration of Environmental Protection Programs.**

The first, "status quo" policy option is not compatible with option II; however, the options are not mutually exclusive for the most part. The four "new direction" options, taken together, can be viewed as a series of complementary changes to improve and reorient the current program.

Four scenarios are also presented to indicate how several options may be combined. For example, one scenario (a combination of options I and III) responds both to the desire to prevent delays and uncertainties resulting from changes in the current regulatory program and to the need to promote greater use of alternatives to land disposal.

The General Accounting Office, among others, has focused on several administrative aspects, including the critical area of enforcement, in a number of reports to Congress. Most recently, a House study has documented critical concerns in the enforcement of both RCRA and CERCLA statutes and regulations.* There are indications of an increased administrative reliance on voluntary compliance and settlements with responsible parties, which by themselves may be effective, but which appear to be linked to substantial reductions in funding for enforcement activities. OTA's study of technical issues and problems, such as the effectiveness of pollution control regulations or the exemption of wastes from RCRA regulation, cannot substitute for congressional examination of the administration of the Federal program. **The policy actions discussed below, regardless of their merits, are not likely to produce favorable results unless enforcement of regulations is effective.**

Common Goals for Policy Options

It is helpful to define specific goals for policy options for purposes of comparison and evaluation. Eight such goals for any practical congressional option are presented below. These goals have been used to evaluate each of the policy options.

GOAL 1

Improved protection of public health and the environment, without undue delays and uncertainties by:

- **reducing the magnitude and hazardous nature of potential releases of waste constituents from all types of waste generation and management facilities,**
- **improving monitoring programs to quickly detect such releases, and**
- **improving corrective actions to mitigate releases.**

GOAL 2

Expand the kinds of hazardous waste federally regulated, recognizing that different levels of regulation under RCRA may be appropriate and desirable.

GOAL 3

Encourage development and use of technological alternatives to land disposal (land disposal includes land and ocean dispersal), such as waste reduction and treatment, to reduce risks resulting from releases of hazardous waste constituents into the environment.

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*U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Oversight and Investigations, report on enforcement of hazardous and toxic substances regulations during fiscal year 1982, October 1982.

GOAL 4

Improve and expand data and information on hazardous wastes, facilities, and health and environmental effects which are necessary for more reliable risk assessments and for the implementation of RCRA and CERCLA by both EPA and the States.

GOAL 5

Improve and expand participation in RCRA and CERCLA by the States through improved definition, implementation, and support of both Federal and State responsibilities.

GOAL 6

Moderate the inevitable increases in the costs of Federal and State program administration and regulatory compliance by industry; and minimize costs associated with site remediation and compensation for further damages to public health and the environment which may result from current practices that could be improved.

GOAL 7

Reduce risks transferred to the future, whether several years or to future generations, and reduce costs of waste management which are externalized and shifted to society in general.

GOAL 8

Reduce public concerns over the siting of hazardous waste management facilities of all types through, for example, improved implementation and enforcement of, government programs.

The Five Policy Options

OPTION I

Continuation of Current Program.

This option assumes that the mandates of both RCRA and CERCLA may be met by the current Federal hazardous waste program. It should be recognized that the present program is not static. EPA has indicated several plans for changes and improvements in the near term.

Unlike the other policy options, no unusual implementation problems and costs are associated with this "status quo" option. Criticisms of the option are generally based on perceptions of current problems or point to unacceptable risks and costs involved in waiting for the program to "prove itself."

OPTION II

A More Comprehensive and Nationally Consistent RCRA Program.

The purpose of this option is to expand the scope and increase the effectiveness of the current RCRA program. The changes discussed below would be carried out by amendment to RCRA, possibly including a schedule for EPA implementation within approximately 6 months to 1 year of enactment. For convenience, all changes in RCRA are presented as one congressional option, although each could be acted on independently, and any combination is possible.

Wastes Regulated.—This change concerns the universe of regulated hazardous waste and the extent of such regulation. The findings of this assessment support consideration of the following measures to regulate, in appropriate ways, more high-priority waste which pose significant threats.

1. **Closing the gap created by the blanket exemption of hazardous waste generated in relatively small quantities.** The objective is to avoid having hazardous wastes managed as nonhazardous, solid wastes in sanitary landfills. In the near term, if a quantity cutoff is used, the prudent approach would be to use a relatively low cutoff, such as 100 kilograms per month (kg/mo) instead of the current 1,000 kg/mo value. In the longer term, however, some measure of the level of hazard of the waste could be used instead. The degree-of-hazard approach does not imply adoption of any particular, or complex, methodology for assessing level of hazard. Regulation would be based on known characteristics of the waste that indicate potential harm to human health and the environment on release of the material into the environment and with significant exposure. However, if it could be demonstrated that relatively small quantities of hazardous waste do not present significant threats (either on a generic or waste-specific weight cutoff basis),

then there could be minimal regulatory control, e.g., notification and reporting requirements, or modification of the RCRA regulations which govern waste generators.

2. **Ending the total exemption for hazardous waste burned as fuels, or as fuel supplements, which may, in some instances, be dispersing unacceptable amounts of hazardous substances into the environment.** Instead, there would be notification requirements for records of what wastes are being burned and where. Also, there would be standards for acceptable levels of releases into the environment, and perhaps some monitoring requirements.

3. **Ending the total exemption from RCRA coverage of liquid hazardous waste sent to publically owned waste water treatment facilities.** There would be instead notification requirements and standards for acceptable amounts of releases and residuals in effluent waters and sludges, supplementing gaps in pretreatment coverage under the Clean Water Act. These requirements and standards would be defined for specific hazardous constituents in a manner consistent with types and concentrations of constituents.

4. **Establishing a category of "special" hazardous waste consisting of high-volume relatively low-hazard waste to be minimally regulated under RCRA.** There may only be notification requirements for generators of such waste.

5. **Developing minimal regulations for the recycling of hazardous waste (or hazardous materials that could become wastes), applicable to all operations, not just "third party" recyclers as is currently proposed.** Due consideration would be given to avoiding the creation of disincentives for recycling, e.g., by only requiring notification of what wastes are being recycled.

6. **Developing lists of hazardous waste to be prohibited from management in landfills, surface impoundments, and deep wells.** These lists should be correlated with technical criteria regarding particularly high risks from possible releases into the environment.

7. **Establishing regulatory criteria for hazardous waste which, although substantial scientific information indicates their hazardous character, have not yet been so defined.** They have not been listed and, when subjected to current EPA tests and procedures, they do not exhibit any of the currently identified hazardous waste characteristics. For example, a number of industrial wastes containing significant levels of dioxins, chlorinated organics, or pesticides are not now regulated as hazardous waste and cannot be shown to be toxic by EPA's test for toxicity (see ch. 4).

8. **Making delisting of hazardous waste more expeditious without, however, compromising protection of the public.** This could be done by using clearer, specific criteria for delisting and by limiting times for evaluation by EPA. To some extent, this action could balance the effects of the preceding actions, which lead to more wastes being regulated. Delisting provides a means whereby site-specific factors or previously unavailable information might mitigate prior estimates of potential hazard. However, one problem that has become apparent in delisting processes should be controlled. Although constituents causing a waste to be originally defined as hazardous may have been removed, the waste may still contain other hazardous constituents in significant concentrations. Such waste should not be delisted, pending further testing. The sole or inappropriate use of the EPA toxicity test should be examined. Adopting a procedure for verification of submitted data should also be examined.

Limited Class Permits.—The engineering design and performance characteristics of some hazardous waste management facilities may be largely independent of location. Class permits may be appropriate for such facilities. However, such facilities should have little probability of release of hazardous constituents, and possible releases should be easily observable through minimal, and required, inspection or monitoring. There is some concern over whether permitting by rule would lead to sufficient protection of the public, such that the loss of public participation in the permitting process is justified. Furthermore, while use of class permits for tanks and containers may be reasonable, these may have to be limited to aboveground facilities because of the difficulty of detecting leaks in underground facilities. Limited class permits may have to be based on detailed technical criteria, in order to avoid permitting of older facilities having unacceptable design and performance features. (For example, construction materials in older facilities may lack adequate corrosion resistance). If Congress is to sanction class permitting without sacrificing protection of the public, then the limited nature of the policy should be carefully defined through legislation. Class permitting need not involve a cutoff of all public participation. Expedited and minimal permit review can be combined with appropriate notification and an opportunity for the public to be heard as part of the permitting process.

Specific Technical Criteria in Regulations.—There are a number of critical components to the RCRA and CERCLA regulations that include little if any specific technical criteria to guide permitting. If Congress is to ensure protection of the public in a consistent way nationwide, then it is necessary to direct EPA to establish specific technical criteria through rulemaking (in contrast to reliance on guidance documents). This would correct the current emphasis on allowing Federal or State permit writers to make critical decisions without either such guidance, or the resources (financial, technical, and human) necessary for making decisions and formulating criteria about extremely complex technical matters. Two areas of particular concern are the RCRA regulations dealing with monitoring for land disposal facilities and the CERCLA regulations dealing with the determination of the extent of cleanup at a remedial site. This is not to imply that EPA is unaware of the problem. Several relevant activities should be noted: draft guidance documents have been prepared by EPA and may lead to specific criteria being used; EPA was under judicial order to promulgate final regulations; and regulations can and may be revised in the future to add more detailed standards.

OPTION III

Use of Economic Incentives for Alternatives to Disposal and Dispersal of Hazardous Waste.

The objective of this option is to shift the balance from disposal and dispersal of hazardous waste into the land or oceans to the reduction of waste at the source, recycling, and treatment. Direct economic incentives would be used to accomplish this objective.

This option is designed to provide **direct** incentives. There are, within the current program, opportunities to promote the use of alternatives to disposal and dispersal through regulatory incentives, including: streamlining of permitting procedures for alternative and perhaps innovative facilities; requirements to use certain alternatives for specific wastes; and increasing the required level of control for disposal and dispersal approaches. Moreover, the current system is significantly increasing the costs of land disposal, compared to a few years ago. While these factors may have beneficial effects, they are often rendered less effective than they could be by uncertainties, ambiguities, and contradictions in the regulatory system as perceived by the regulated community or because they limit choices in too general a fashion. The use of direct economic incentives can be viewed as a complement to regulatory incentives and to the use of the legal system. While legal actions may motivate the use of alternatives to land disposal, the perceived effects are often uncertain and may not occur until long after the adverse effects of land disposal practices occur.

This policy option should be viewed in the context of current legislation concerning hazardous waste management. CERCLA was enacted because of the recognition that unacceptable risks have been inherited from certain past waste management efforts that were too shortsighted. **The connection between CERCLA and RCRA has received insufficient attention. Too often they are viewed as separate programs, rather than as two components of the Federal hazardous waste program.** The need for future expenditures of public funds to clean up hazardous waste sites should be minimized.

Congressional action to implement this option could occur through an amendment to RCRA or CERCLA or as new legislation. There are no apparent technical or institutional obstacles to adoption, but a major issue would be what types of incentives to provide. Before discussing several types of economic incentives, the concept of a **hierarchy of alternative management strategies** is examined to provide a context for considering this option.

A Hierarchy of Alternative Management Strategies

A major purpose of chapter 5 is to demonstrate the applicability of a relatively large number of alternative technological approaches to hazardous waste management. Such technologies provide means for the reduction of waste generation, the destruction of waste, and the disposal or dispersal of waste in the environment. **Different alternatives are appropriate for different wastes and locations.** In chapter 4, it is noted that, nationwide, land disposal continues to be used for most hazardous waste (although it varies substantially among States), and in chapter 5 the uncertainties concerning the use of ocean disposal are discussed.

The following hierarchy provides a useful framework for understanding the potential use of alternatives to disposal and dispersal of hazardous waste, consistent with good engineering practice and sound economics:

1. **waste reduction** at the source through, for example, process modifications;
2. **waste separation, segregation, and concentration** through available engineering approaches in order to facilitate identification of the waste and the application of the remaining steps;
3. **material recovery,** either onsite or offsite, to make use of valuable materials, including the use of waste exchanges so that a (potential) waste for one generator can be made available as a resource for another operation;
4. **energy recovery** from (potential) waste or its components, perhaps as a fuel supplement;
5. **waste treatment** to reduce the hazard level and possibly the amount of waste requiring disposal; and
6. **ultimate disposal or dispersal** (preferably of residues from previous steps, of materials pretreated to reduce mobility after land disposal, and of untreatable wastes) in a manner that holds release of hazardous constituents into the environment to acceptable levels.

Such a systematic ordering of waste management options presents a number of advantages. For example, permanent solutions to waste problems are more likely to occur at some stage prior to disposal and dispersal. Consequently, fewer risks and costs are shifted to the future. An initial emphasis on waste reduction could significantly reduce costs of waste management and, in some instances, avoid them altogether. Using materials as resources, rather than discarding them, at once prevents them from becoming wastes and provides direct economic benefits. If less hazardous wastes are produced and regulated by promoting the use of alternatives 1 through 5 of the hierarchy, and if there are reduced administrative activities (such as inspection) for treatment and disposal facilities, then the costs of administering a regulatory program and of remediating uncontrolled sites could be reduced.

Specific factors concerning waste, plants, and companies should play their normal role in economic evaluations of alternatives. Moreover, for some waste only management alternatives 5 or 6 will be technically feasible or cost effective. The above listing does not imply that alternatives 2 through 5 do not involve any potential release of waste or their constituents into the environment. Techniques for these options require some regulatory coverage to monitor and hold such releases to acceptable levels. For example, energy recovery through the burning of waste as fuels poses problems of releases of hazardous constituents into the environment. Such regulation can provide information useful in enforcement efforts and for understanding how generic types of waste can be managed other than by disposal and dispersal approaches.

The idea of the hierarchy presented above did not originate with OTA. It has been recognized for some time by those concerned with waste management in industry and government. In 1976, before the passage of RCRA, EPA offered a position statement on effective hazardous waste management that included the above hierarchy as a ranking of preferred alternatives. As recently as 1982, EPA reiterated its support of the 1976 position.[10]

Nonetheless, there has been little programmatic support of the concept of a waste management hierarchy. Although RCRA gave some attention to reuse, recovery, and recycling, there have been few programs providing incentives to waste generators, nor have there been transfers of technology and information encouraging this strategy. As for EPA's R&D activities, in fiscal year 1983 the total effort related to alternatives to land disposal amounts to about 10 percent of all hazardous waste R&D, or $4.4 million. From another perspective, 10 years of such funding for this purpose would only be equivalent to the costs of cleaning up several major uncontrolled land disposal sites. (See ch. 7 for a discussion of all current EPA expenditures.)

Types of Incentives

Considering the generally accepted objective of minimizing government expenditures, OTA believes that it is impractical to suggest major incentive programs based on direct, budgeted expenditures. Also, the use of economic incentives raises questions concerning the appropriate placement of burdens on industry. For such reasons, this option consists of three components: a fee system on generated wastes to influence management choices, procedures addressing capital needs of alternatives to disposal and dispersal, and consideration of R&D problems that might prevent the development of alternatives.

A Fee System.—There is a trend toward State use of fee systems, some of which are based on wastes, both to raise revenues and to influence choices among hazardous waste management alternatives, although results of these relatively new programs are mixed. California, Kentucky, Missouri, and New York impose fees on waste generators. The CERCLA program, at the Federal level by comparison is based on the collection of a fee or tax on the production of petroleum feedstocks and specified chemicals, raising 87.5 percent of the $1.6 billion fund. Many critics of this approach believe that the fund should have been financed through a "tail-end" fee or tax on actual waste generated, rather than on "front-end" feedstock materials that only indirectly, and to different degrees, lead to hazardous waste generation. A strong disincentive is thus inadvertently established which penalizes those generators choosing to minimize waste generation. However, there was insufficient information on waste generators originally available to facilitate such an approach. When collection under CERCLA expires in 1985, it is likely that substantial sums will continue to be required to clean up uncontrolled sites. EPA's original estimate of several years ago was that $44 billion might be required. There have also been indications from the administration that it is currently disinclined to seek reauthorization of the tax collection program. **Continuation of the current CERCLA fee system offers no direct incentive to alternatives to land disposal, although continued experience with CERCLA may prove to be an effective indirect influence on use of such alternatives.**

An approach that would satisfy several objectives could be based on the use of the CERCLA funding mechanism for RCRA purposes, using the tail-end fee system. This would involve shifting the collection of CERCLA moneys (including the post-closure liability trust fund to start in 1983) to hazardous waste generators. For such an approach to be effective, fees would have to be reduced, on a unit-weight basis, when: 1) alternatives to disposal and dispersal were used by the generator, either onsite or offsite, and 2) the hazard level of the waste or residue finally disposed of was relatively low.

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[10] Federal Register, vol. 41, No. 161, pp. 35050, 35051, 1976; U.S. House of Representatives, *EPA Journal*, July-August, p. 19, 1982; and testimony of Rita M. Lavelle, U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Natural Resources, Agriculture Research and Environment, Dec. 16, 1982.

The critical feature of such a system is that such a fee should be substantially greater (perhaps double) for disposal and dispersal options and substantially lower for low-hazard or treated waste (perhaps by half). A fee discrimination would provide the desired economic incentives for alternatives to disposal and dispersal. Moreover, the discriminatory ratios and/or the amounts of the fees on land-disposed waste might be increased over time, as waste volumes decline and after ample time has been given for adopting alternatives. A zero tax for those wastes (or portions of them) recycled for materials or energy that would otherwise become hazardous wastes would appear equitable and desirable. However, there is a need for carefully determined definitions for recycling (as well as for what is a hazardous waste), otherwise a waste-fee approach could lead to inappropriate removal of waste from the system.

Can fees on generated hazardous waste raise sufficient revenues? If one accepts the currently quoted figure of 41 million tonnes per year of RCRA-defined hazardous waste generation, an **average** fee of $10 per tonne would raise about the same annual revenues as CERCLA now does. If total waste generation is much higher, as it may be (see ch. 4), or if more wastes are brought under the RCRA program, then fees might be reduced somewhat.

For disposal and dispersal options, with high fees of perhaps $10 to $20 per tonne, costs would increase by less than 10 to 40 percent for a disposal cost range of $50 to $200 per tonne, and perhaps by less if the national waste stream is found to be much greater than the current estimate. However, there are low-hazard high-volume wastes for which disposal or treatment may only cost $10 to $20 per tonne, and for which fees should be lower than the average. Table 5 illustrates a waste-fee system which has been proposed in Minnesota. The structure of this system is strongly biased against land disposal, particularly for liquid wastes. It also favors onsite over offsite management, a bias often defended because of advantages associated with not transporting hazardous materials, rather than on any intrinsically superior level of management at onsite facilities.

Suggesting a national waste fee system is likely to raise a number of problems and concerns. A summary of the key issues is presented in table 6.

The underlying philosophy of this approach would be to reward those who minimize future risks and costs to society through the use of preferred alternatives which permanently reduce the risks involved in hazardous waste management. As existing uncontrolled sites are cleaned up, future uncontrolled sites made less likely, and hazardous waste generation reduced, the fees for non-land-disposed wastes could eventually be decreased. Morever, such an incentive system would encourage efforts to reduce the amounts of waste generated. The uses of the fees collected could be expanded, as has been recommended, perhaps to deal with injuries and damages directly associated with mismanagement of hazard-

Table 5.—Illustration of a Hazardous Waste Generator Tax Structure

Waste management category	Tax on solid waste ($/tonne)	Tax on liquid waste ($/tonne)
Land disposal	42	85
Offsite:		
Land disposal after treatment	21	42
Treatment	11	21
Onsite:		
Land disposal after treatment	11	21
Treatment	5	11
Recycling/reuse; used crankcase oil	0	0

NOTE: In addition to this tax, to support a State Superfund, a hazardous waste generator fee (a minimum fee plus a fee dependent on the quantity of waste generated) was also proposed to support State administrative costs for hazardous waste programs. A provision was included to exempt small generators.

SOURCE: Minnesota Conference Report H.F. No. 1176, Mar. 19, 1982.

Table 6.—A National Waste Fee System: Summary of Key Problems and Concerns

Problem or concern	Comments
Use of the legal system and insurance requirements could be used as nonregulatory approaches instead of the fee system.	They are useful; but affect management choices slowly because of time delays and uncertainties.
There is insufficient capacity for treatment alternatives to land disposal.	Unused capacity now exists; a fee system would remove market uncertainties and stimulate investments. Waste reduction efforts do not face this problem.
Industry and consumers may face heavy economic burdens.	Programs to address capital and R&D needs are required. Action soon would provide time for planning. Small effects on consumer prices would be equitable.
Illegal dumping would be increased.	Both regulatory enforcement and policing efforts remain necessary.
It would be more efficient to rely on State fee systems.	Not all States will or can adopt waste fee systems. Nor will they have similar programs. For consistency and equity nationwide, a Federal system is necessary. Otherwise pollution havens may form.
Eventually, there may be extremely high fees on remaining and, perhaps, unavoidably land-disposed waste.	Abrupt changes in management choice not likely. More waste may be regulated with lower fees. CERCLA and administrative needs will eventually decline. Fees can be lower for high-volume, low-hazard wastes.
International competitiveness of some industries may be reduced.	Capital and R&D assistance, and time for planning are necessary. Some industrialized nations already use more treatment options.
A national waste fee system distorts the marketplace.	Such a system is a corrective action; presently costs and risks are transferred to people (now and in the future) who do not receive corresponding benefits.

SOURCE: Office of Technology Assessment (see ch. 3 for a complete discussion).

ous wastes.[11] Fees could be collected by States, and it might be advantageous to distribute a specified percentage of the moneys collected by a State to its program. This could promote the replacement of varying State fee programs with a uniform national system, at least for federally regulated waste. A uniform system could minimize potential effects on interstate commerce (e.g., States with fees which are high relative to other States are less able to attract industrial activities producing hazardous waste).

Capital Needs.—A major obstacle to the adoption of measures to reduce waste generation or hazard levels is the need for capital investment for new or modified equipment or facilities, either by waste generators or commercial waste managers. A **Federal loan program** could be instituted, which offered low interest rates, and perhaps long terms for repayment, for capital expenditures on existing or new facilities directly related to waste or hazard reduction. Alternatively, the Federal program might guarantee private sector loans, or make available tax free bonds to finance loans. Technical guidelines could be established and the administration of loan evaluations and approvals could be shifted, for the most part, to the State level. CERCLA funds not spent for cleanups, or more likely a designated portion of moneys collected under a new fee system, might be used as a source of funds for loans. A fixed fraction of such fee- or tax-generated funds might be designated for these types of loans. One recent study that examined using government loan incentives for resource recovery equipment for hazardous waste generated in the electroplating industry concluded that such a program could be quite effective.

Another means of addressing capital needs is the use of **tax credits.** A special, time-limited investment tax credit to spur capital investments could be offered for those uses directly related to reduction of waste amounts or hazard levels. Although this is a traditional approach to achieving a desired goal of society, it has received criticism due to the loss of revenues to the government. However, the case of hazardous waste presents a particularly good example of how spending promoted by a tax benefit could, in the long-term, markedly reduce government expenditures. Moreover, a special tax credit of 10 percent (in addition to any broad investment tax credit) likely would lead to reductions in government revenues of several hundred million dollars annually over perhaps a 5- to 10-year period. An interesting possibility would be to use some portion of the funds collected under a waste generator fee system to compensate the U.S. Treasury for all or part of the lost tax revenues. This would be consistent with a philosophic commitment to rewarding those who reduce the magnitude of the hazardous waste problem, while requiring those who continue to place a burden on society to pay the costs of that burden. The study mentioned above concerning the electroplating industry also concluded that a special investment tax credit for resource recovery investments could be effective.

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[11] "Injuries and Damages From Hazardous Wastes—Analysis and Improvement of Legal Remedies," a report to Congress in compliance with sec. 301(e) of the CERCLA, September 1982. (By an independent group of attorneys.)

Assistance for R&D Efforts.—Alternatives to disposal and dispersal meet with another obstacle in that often technologies for, say, process modification or for treatment of particularly difficult wastes require applied R&D efforts before they can be commercially feasible. Increased Federal support of private sector R&D, including pilot plant efforts, could therefore be very useful—relatively small sums might produce very large benefits. In order to allay objections to using Federal funds, it might be possible to structure R&D assistance so as to recover the Federal investment, perhaps through long-term low-interest loans to be repaid upon successful commercialization of the technology. Profit-sharing and exclusive licensing arrangements with payments to the government are also possible. Illinois commits a portion of the revenues obtained from fees on waste for R&D projects.

OPTION IV

Development and Potential Use of a Hazard Classification Framework.

This option provides for the development of a hazard classification framework for risk management that, if feasible and beneficial, would be introduced into the RCRA regulatory program. The framework would be based on detailed technical criteria establishing several different ranges (or classes) of hazard levels. There would also be a corresponding classification system for facilities. The waste and facility classification would provide means to:

1. set priorities, such as determining what areas need to be addressed first in obtaining more accurate and reliable data;
2. establish different levels of monitoring requirements; and
3. establish appropriate levels of regulatory control, including restrictions on certain management technologies and types of facilities, exemptions from full regulatory coverage, and different levels of performance standards for RCRA regulations covering the operation of waste management facilities.

Although using classifications seem to suggest considerable complexity and drastic changes in the regulatory structure; neither is required. What is envisioned is using an improving scientific base to structure the evolving RCRA regulatory program. For example, some solid wastes addressed under subtitle D of RCRA would be brought under subtitle C control, but, for almost all these wastes, there would be minimal regulatory requirements (such as reporting and notification requirements). Similarly, some low-hazardous waste currently under subtitle C might receive less regulation than they now receive, and perhaps be removed from the hazardous category altogether. Some high-hazardous waste would receive more stringent regulation than they now receive. For most hazardous waste, however, the classification approach would have little effect.

Congressional action could be accomplished by amendment to RCRA, by initially directing EPA, or another agency, to develop a waste and facility classification system and a plan for its implementation. Such an analytical effort could take several years and would require additional Federal appropriations of perhaps $5 million to $10 million. Presumably, no new data would be acquired for this initial study phase (which for health and environment effects data is an expensive undertaking), but rather existing data bases would be used. The second level of congressional action would consist of an evaluation of the study, and a decision: 1) to either move ahead with implementation; or 2) to pursue a second, more detailed study, possibly involving the acquisition of new data, followed by integration of the hazard classification framework into the RCRA program; or 3) to discontinue the option. Implementation, or a second study, could take several years, and the costs are difficult to estimate.

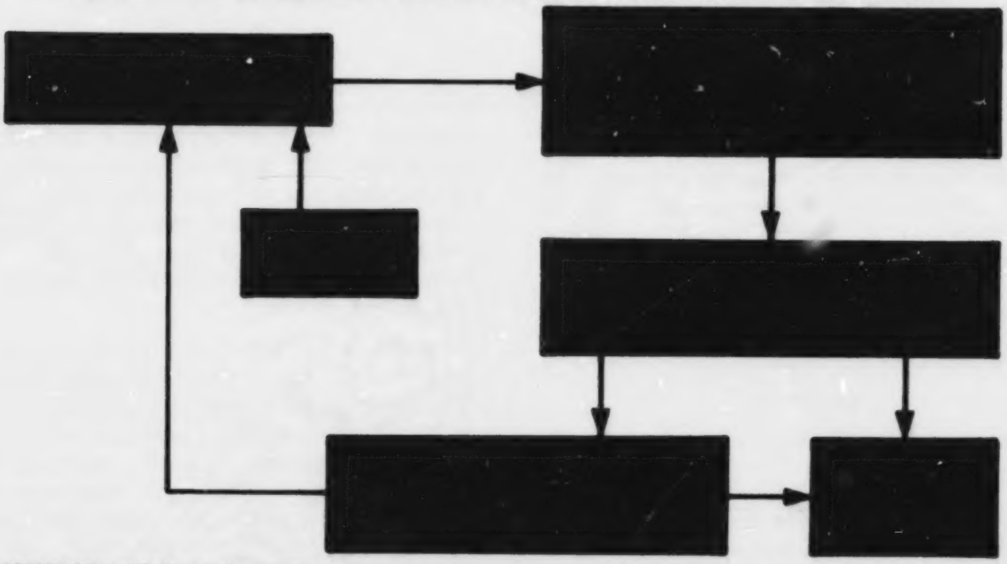
Brief Summary of a Hazard Classification Framework

The key elements of this particular application of the hazard classification concept are presented in figure 2. The approach is compatible with the hierarchy of alternative management strategies presented earlier, particularly the goal of reducing the amount and hazard level of wastes.

Several important elements, each requiring reliable information to be obtained by the Federal program, form the basis of this scheme. Some of the information may be currently available in varying degrees of completeness and accuracy. The collection of other necessary data may require substantial efforts. There are three elements of the system:

1. **The critical characteristics of those constituents of the waste that largely determine its hazard classification.** Classifying wastes is a major undertaking that requires a carefully designed analytical framework and substantial amounts of information on a broad variety of factors, including concentrations of hazardous constituents, toxicities, mobilities through various environmental media, environmental persistence or bioaccumulation, and various safety characteristics. It is not sufficient merely to use information on the most hazardous constituent, or the one present in the largest amount, to fully assess a particular waste. There currently is no standard procedure to describe the hazard level for a physically and chemically complex waste, although there are indications that it is technically feasible to develop one (see ch. 6).

Figure 2.—Risk Management Framework Based on Waste and Facility Classification



SOURCE: Office of Technology Assessment.

2. **Consideration of those factors used to determine facility classes:**
    - **The chemical and physical characteristics of the waste that limit treatment and disposal options.** This information would indicate whether the waste is aqueous or nonaqueous, inorganic or organic, and whether it is a liquid, sludge, or bulk waste with a high-solid content. It also would be necessary to know if the waste contains toxic metals, particular types of known toxic organics, corrosive acids, explosives, or highly ignitable substances.
    - **Information on the broad range of technology options that are commercially available and technically feasible.** Considerable information is needed on the designs of technologies, actual performance characteristics, problems related to operation and maintenance, and requirements for trained personnel. Problems related to patented and proprietary information may have to be addressed.
    - **Performance standards for various technology options, used for setting the level of effectiveness (risk reduction) of the technology, or the level of acceptable release of hazardous constituents from the facility.** For waste treatment operations, performance standards may be given in terms of changes to be effected in various critical characteristics of the waste. After incineration, for example, the percent of one or more waste constituents destroyed, perhaps in conjunction with acceptable levels of emissions, can be used. (This is similar to what is used now.) It is important that waste classification and its linkage to facility class be technically sound in order to avoid "technology forcing" when, in fact, available technology can achieve desired levels of protection. For disposal operations, performance standards may be given in terms of acceptable levels of release over specified periods of time. Standards would vary with levels of hazard.

    In general, different types of performance standards will be required for different disposal and treatment technologies and may be required for different levels of hazard. Selection of performance standards depend on the regulatory functions deemed most important. What is attractive from the perspective of ease of enforcement or compliance may not be as attractive to those concerned with risk management.
3. **Matching of waste and facility classes.** This is the key step—ensuring that levels of risk are consistent across both waste and facility classes. For a particular waste class, different technologies within the same facility class should offer similar risks. It must be emphasized that all suggested uses of hazard classification assume that **only a few classes would be required and are practical.** Usually high, medium, low, and no hazard (essentially a decision to consider the waste as an ordinary solid waste) waste classes, and corresponding facility classes, are envisioned.

An Illustration of the Classification Approach.—Two types of questions are usually raised concerning the hazard classification approach. What types of data are used to distinguish different waste hazard classes? What are the regulatory implications of establishing different waste hazard classes? Table 7 provides examples of how the classification approach can be developed and used, but it should be emphasized that the examples shown are strictly for illustrative purposes and do not constitute any endorsement or recommendation by OTA.

OPTION V

Planning for Greater Integration of Environmental Protection Programs.

The purpose of this option is to integrate administratively (and, if necessary, statutorily) a number of existing environmental programs that affect hazardous waste management and regulation. Policies and programs that lead to inefficient overlapping regulations, gaps in regulatory coverage, and inconsistent regula-

Table 7.—Illustrative Examples of a Potential Hazard Classification Framework[a]

Examples of scientific criteria for waste definition[b]	Examples of varying levels of regulatory control, and restrictions on waste management practices[c]
High hazard	
1) Acute toxicity: Oral rat LD_{50} < 5 mg/kg Aquatic LC_{50} < 1 mg/kg 2) Chronic toxicity: Equivalent concentration of persistent compounds > 1.0% Toxic metals 100 to 10,000 × DWS Suspected bioaccumulative carcinogens	Limited to Class I facilities; cannot be placed in surface impoundments, landfills, injection wells, land farms No monitoring exemptions Incineration DRE > 99.99; as fuel, can only be burned in industrial boilers Cannot be stored more than 30 days without permit No exemptions for small generators Recycling facilities to be permitted
Medium hazard	
1) Acute toxicity: Oral rate LD_{50} 5 to 500 mg/kg Aquatic LC_{50} 1 to 100 mg/kg 2) Chronic toxicity: Equivalent concentration of persistent compounds 0.01-1.0% Toxic metals 100 × DWS Suspected nonbioaccumulated carcinogens 3) Corrosive, reactive, ignitable	Limited to Class I and II facilities; cannot be disposed above or within 5 miles of a ground water aquifer Incineration DRE > 99.9; cannot be burned in residential boilers Can be stored up to 90 days without permit Small generators exempted up to 10 kg/month Recycling facilities to be permitted
Low hazard	
1) Acute toxicity: Oral rat LD_{50} > 500 mg/kg Aquatic LC_{50} > 100 mg/kg 2) Chronic toxicity: Equivalent concentration of persistent compounds < 0.01% Toxic metals 100 × DWS 3) Corrosive, reactive, ignitable	Limited to Class III facilities, and to Class I and II facilities for which no reactions with wastes are likely Incineration DRE > 99.0; can be burned in industrial and residential boilers Can be stored up to 180 days without permit Small generators exempted up to 100 kg/month Only reporting requirement for recycled waste and recycling facilities

DWS—drinking water standards

[a] The examples shown are strictly for illustrative purposes only, and do not constitute any endorsement or recommendation by OTA.

[b] Source: Adapted from system in Washington; see discussion in ch. 6.

[c] Source: Office of Technology Assessment.

tions would be addressed. Insufficient integration among different EPA programs and other executive agencies may be leading to duplication of effort or unawareness of the extent of data and technical resources that are available.

A number of hazardous waste activities are now regulated under different statutes, and within EPA several different groups administer activities related to hazardous waste. There are also programs in several other executive agencies related to hazardous waste; these do not appear to be highly integrated. The language in RCRA that mandates integration with other acts has proven to be too inexact, and EPA's efforts in this area do not appear to have a high priority. Ocean disposal or dispersal of hazardous waste falls under the Marine Protection, Research and Sanctuaries Act. Some injection wells that may be used for waste disposal fall under the Safe Drinking Water Act and others under RCRA. Hazardous waste streams destined for municipal water treatment plants fall under the Clean Water Act. A number of aspects of regulating releases into the air or water from hazardous waste management facilities fall under the Clean Air and Clean Water Acts. Some wastes are and may be regulated under the Toxic Substances Control Act (TSCA). A recent study for EPA concluded:

> A number of Federal statutes govern aspects of the hazardous waste problem. The statutes in combination do not cover many of the major sources and types of hazardous waste releases, however.[12]

Congressional action for this option would consist, first, of mandating a comprehensive study of integration by EPA or some other agency, including formulation of an integration plan. The second phase would consist of congressional examination of the study and plan. If deemed necessary, legislative action would then implement the plan.

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[12] "Evaluation of Market and Legal Mechanisms for Promoting Control of Hazardous Wastes," draft, Industrial Economics, Inc., September 1982.

The existence of overlapping jurisdiction to regulate hazardous waste activities is not necessarily counterproductive, confusing, or undesirable. The goal should be twofold:

1. ensuring that hazardous wastes that might pose significant risks to human health and the environment do not escape regulation, and
2. promoting the integration of hazardous waste control and other pollution control with legislation so that they can support each other, consistent with the statutory requirements and goals of each program.

There is now no mechanism for ensuring: 1) that facilities disposing of similar wastes but regulated under different acts will be consistently regulated; or 2) that a facility permitted under RCRA is not **also** disposing, without a permit, other hazardous wastes regulated under other acts.

Moreover, although both RCRA and CERCLA are managed within the same division of EPA, there appears to be little coordination of efforts between the two programs. Chapter 7 presents three examples that illustrate additional problems associated with inadequate integration in the current Federal program.

Two Steps Toward Integration of Environmental Programs

There are two phases to this option, both of which should anticipate the need for effective public participation in order to address concerns over changes that might lead to delays. First, EPA (or perhaps some independent body) could develop a plan for the improved integration of programs related to hazardous waste. The plan would focus on statutory changes required to implement a comprehensive integration, with emphasis on the permitting of facilities.* The study also should examine obstacles to integration which occur at the State level, the costs of integration incurred at Federal and State levels, probable improvements in protection of human health and the environment, and impacts on waste generators.

The second phase would include congressional examination of the study and plan, and an examination of how administrative and statutory changes could be achieved. Congress could also examine changes in EPA's organization that would be necessary to integrate, and if integration would require legislation.

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*These statutory changes need not—and probably would not—involve integrating the various environmental laws themselves.

Summary Comparison of the Five Policy Options

This section presents the relative benefits of all five options in a convenient form and is intended to facilitate the comparison of the five options apart from the consideration of costs and time involved. Options II through V can be viewed as a series of complementary actions, taken progressively over time, or as separate individual actions offering particular benefits relative to one or more of the eight goals. Moreover, while option I (status quo) and option II (modifications in RCRA) are mutually exclusive, options III, IV, and V are compatible with option I.

Options II through IV appear to require approximately the same level of initial congressional appropriations, about $5 million to $10 million each. There are, however, no means of reliably estimating longer term costs, or cost savings for government, industry, or the general public. The five options have been presented in order of increasing time required for preliminary studies and implementation. If immediacy of implementation is an important consideration for some policymakers, then clearly options I, II, and III are the most attractive.

The policy options have been compared in two ways. In neither comparison, however, has any attempt been made to demonstrate that any one option is "best," or even that one option is better than another. In addition to the eight goals, considerations of time and cost, along with specific objections to particular options, can make any option either more or less attractive.

Table 8 summarizes in brief narrative form the key advantages and disadvantages of each option. Table 9 presents an evaluation of how each option, relative to the others, satisfies each of the eight goals. This evaluation is necessarily somewhat subjective and judgmen[illegible]

In presenting the five policy o[illegible]A is aware of the need to justify ad[illegible]deral expenditures and possible i[illegible]n short-term costs to the private secto[illegible]rent public and private sector costs for hazardous waste management are substantial, approximately $4 billion to $5 billion annually. Regardless of any policy action, these costs will increase markedly in the future as both the RCRA and CERCLA programs become more fully implemented and possibly as the expected economic recovery leads to an upturn in hazardous waste generation.

The total appropriated funds for options II through V might be $50 million. This represents about 25 percent of annual total Federal and State expenditures for hazardous waste activities. It also represents about 1 percent of the current total public and private sector annual costs of administering and complying with RCRA and CERCLA.

There are considerable uncertainties concerning longer term costs to public and private sectors for implementing options II through V. Nonetheless, there is reason to believe that both the short- and long-term costs of carrying out all four policy options may be more than offset by the potential benefits, only some of which can be viewed in strictly economic terms. The chief areas of potential cost savings are: reductions in the number of haz-

Table 8.—Key Advantages and Disadvantages of the Five Policy Options

Key advantages	Key disadvantages
I. Continue current program	
• Current program stabilized and resources already invested utilized • Participation by States improved • Short-term private and public sector costs moderated	• Protection of public health and environment may be weaker than possible and desirable • Risks and costs may be unnecessarily transferred to the future • Land disposal continues to be used extensively
II. A more comprehensive and nationally consistent RCRA program	
• Protection of health and environment improved and made more consistent nationally • More hazardous waste controlled • Data base improved	• Short-term private and public sector costs increased • Progress of present program could be slowed unless additional resources are provided • Technical resources and data may be insufficient
III. Economic incentives for alternatives to land disposal	
• More waste reduction and treatment • Costs for improved protection more equitably distributed • Public concerns over siting alleviated	• Near-term costs to industry increased • Uncertain effects on firms, communities, and international competitiveness • Illegal dumping may increase
IV. Development and potential use of a hazard classification framework	
• More waste regulated at levels consistent with hazards posed • Fewer risks and less costs transferred to the future • Improved technical support for State programs	• Major effort needed to improve data base • Unnecessary complexity may be introduced • Long-term costs for implementation uncertain
V. Planning for greater integration of programs	
• Gaps, overlaps, and inconsistencies in regulatory coverage reduced • Reduced transfer of risks and costs to the future • Public confidence in Federal program improved	• Considerable administrative and institutional difficulties • Possible interruptions in ongoing programs • Congressional action on necessary legislative changes may be complex

SOURCE: Office of Technology Assessment.

Table 9.—Comparative Ranking of Policy Options for Each Policy Goal

Goals	Most effective				Least effective[a]
1. Improve protection of human health and the environment without undue delays and uncertainties	II	III	I	IV	V
2. Expand universe of federally regulated hazardous waste	II	IV	V	I	III
3. Encourage alternatives to land disposal	III	IV	II	I	V
4. Improve data for risk assessment and RCRA/CERCLA implementation	II	IV	I	V	III
5. Improve and expand RCRA/CERCLA participation by States	III	II	I	IV	V
6. Moderate increases in costs to governments for administration and industry for compliance	I	IV	V	II	III
7. Reduce risks and costs transferred to the future; reduce costs of management shifted to society in general	III	II	IV	V	I
8. Reduce public concerns over siting facilities	III	II	V	IV	I

Policy options:
I. Continuation of current program.
II. A more comprehensive and nationally consistent RCRA program.
III. Economic incentives for alternatives to land disposal.
IV. Development and potential use of a hazard classification framework.
V. Planning for greater integration of environmental protection programs.

[a] Least effective does not imply total lack of effectiveness; all rankings are strictly for ordering options and do not imply any absolute level of effectiveness.

SOURCE: Office of Technology Assessment.

ardous waste sites requiring very expensive cleanup and reductions in damages to people and to the environment which entail substantial costs for treatment, remediation, and compensation. Relatively small percentage savings imply substantial absolute dollar savings. For example, if all four options led to a net savings of only 1 percent in the future annual national costs associated with hazardous waste (currently about $4 billion to $5 billion and rising), the savings in one year would exceed the initial costs of implementing the options. It is possible that in the long-term, implementation of the options could lead to considerably greater economic benefits.

Four Scenarios

As discussed in the previous section, it is possible to implement various combinations of the five policy options. The purpose of the following discussion is to illustrate four such combinations. The four scenarios have been developed by making certain simplified assumptions about varying perspectives on the need and methods for improving the current Federal waste program.

SCENARIO I

Current RCRA regulations are adequate, but alternatives to land disposal need encouragement. Options I and III are adopted.

Many believe that the current RCRA regulations are satisfactory and should be given an opportunity to prove themselves effective. Changes in the regulatory program, it is argued, are unnecessary and would be counterproductive to the extensive efforts made since the passage of RCRA. Nonetheless, it is also generally recognized that from a long-term perspective, unnecessary risks and costs may be transferred to the future by disposing of many hazardous wastes in the land. There is equal concern that congressional action in this critical period of development should be expeditious and well defined.

Accordingly, this scenario consists of adopting option I (maintaining the current RCRA regulatory program) and also adopting option III (providing direct economic incentives for alternatives to land disposal). Option III is compatible with option I, since it involves nonregulatory "market" methods of reducing future releases of hazardous constituents. Option III consists of three critical components:

1. a system of fees or taxes on waste generators (to replace the current funding mechanism for CERCLA) based on quantity of waste, level of hazard, and management practices, in order to promote management choices of alternatives to land disposal;
2. methods for meeting the initial capital needs of those waste generators and commercial facilities that decide to reduce waste generation and to implement treatments reducing hazard or volume levels; and
3. support for R&D efforts that may be necessary before waste and hazard reduction can be accomplished commercially.

SCENARIO II

Specific changes are needed to strengthen RCRA, and an effort is needed to integrate and streamline the entire Federal hazardous waste program which has evolved in a piecemeal fashion. Options II and V are adopted.

The choice of option II is based on the desire to modify and improve the existing RCRA regulatory program. The specific actions included in option II would close a number of existing gaps in regulatory coverage of waste, restrict certain wastes from land disposal facilities, and introduce more technical criteria to set nationwide standards, improve the delisting process, and introduce limited class permitting. However, to address broader concerns over gaps, overlaps, and inconsistencies in regulatory coverage, option V would also be adopted. Option V moves beyond the analysis of RCRA regulations to examine problems related to insufficient integration between RCRA and CERCLA, among the various environmental protection statutes, and among the various executive agencies having programs associated with hazardous waste. These two options combine both short- and long-term approaches to obtaining a more effective, efficient hazardous waste program.

SCENARIO III

The current RCRA program needs improvement and a nonregulatory approach is also needed to shift waste management choices away from land disposal toward waste reduction and treatment efforts. The most expeditious congressional actions are required. Options II and III are adopted.

Option II would result in the improvement of RCRA regulations to better provide short- and long-term protection of human health and the environment. However, uncertainties concerning the effect of the regulations on shifting management choices away from land disposal, along with enforcement problems, would probably remain. To complement the regulatory approach of option II, option III is used to introduce direct economic incentives for alternatives to land disposal. The combination of these options would reinforce the connection between RCRA and CERCLA. Federal fees on hazardous waste, increased for land disposal and for waste with higher hazard levels, can be used to fund CERCLA and State hazardous waste programs. With a fee system, the life-cycle costs of waste management could be internalized by increased costs to responsible parties and to consumers of hazardous waste-intensive products.

SCENARIO IV

The current RCRA regulatory program should be maintained, but some long-term efforts to improve the program should also be pursued. Adopt options I, IV, and V.

Options IV and V are compatible with the current program in the near term, since both initially involve studies before changing the current program. The introduction of hazard classification at some future time does not imply any fundamental change in the RCRA regulatory structure. Similarly, a plan for regulatory integration resulting from option V would not require a restructuring of RCRA regulations. Both options IV and V can be viewed as evolutionary refinements of the current program, and this adoption would not necessarily jeopardize the stability of the present program.

CHAPTER 2

Introduction

Background

Uncontrolled or careless management of industrial waste, with consequent releases of hazardous constituents into the land, water, and air, is generally understood to present a substantial threat to both public health and to the environment. Prior to passage of the Resource Conservation and Recovery Act (RCRA) by Congress in 1976, few States had regulatory programs for hazardous waste. Moreover, Federal programs concerned with air and water quality caused some changes in industry which increased the generation of solid, hazardous waste. Clean air and water regulations also promoted the use of pollution abatement facilities which themselves produced hazardous residues. Experience with more conventional forms of industrial and municipal solid wastes provided few solutions for managing more complex and chemically stable hazardous waste.

National awareness of solid and liquid hazardous waste problems increased dramatically in the mid to late 1970's with widespread concern over mismanaged waste, indiscriminate dumping of uncontainerized liquid waste, and infrequent, but highly visible transportation accidents. Mismanaged waste created serious problems both by the release of harmful substances into the environment and because of the direct exposure of waste handlers and the public to such waste.

It also became clear that even well-intentioned and accepted management of hazardous waste, particularly the use of landfills, surface impoundments, and lagoons, could result in a substantial threat. This threat resulted from the potential, but difficult to assess, slow leakage of waste constituents, or leachate (resulting from the interaction of water or other solvents and waste), through the soil and into underground water supplies, which were or could become sources of drinking water. A sense of urgency regarding hazardous waste issues was also prompted by several other important factors. These included:

- an increase in public sensitivity to the toxic properties of many substances which sometimes were long-lasting;
- an increase in attention to the real or potential links between toxic substances and human and animal cancers; and
- an increase in public demands for protection from pollution of all types.

It became evident that the proper management of hazardous waste, whether newly generated or previously disposed of, posed substantial challenges. Studies revealed that some hazardous waste generated and disposed of decades before had led to undetermined, but possibly very large amounts of dangerous substances distributed in and on the land in many areas of the Nation. Moreover, some previously abandoned disposal sites with uncontrolled releases of waste into the environment were not effectively addressed by RCRA, which was primarily concerned with proper management of present and future hazardous waste. Because of the many hazards posed by uncontrolled hazardous waste sites, both active and inactive (particularly those abandoned sites whose ownership was unknown), Congress passed the Comprehensive Environmental, Response, Compensation, and Liability Act of 1980 (CERCLA), which became better known as Superfund. Problems associated with the identification of especially threatening uncontrolled hazardous sites became prominent, including locating them, characterizing their contents, detecting the nature and extent of releases into the environment, substantiating actual or potential adverse impacts on health and the environment, and developing cleanup techniques and plans.

Since the passage of RCRA and CERCLA, a number of additional problems have arisen.

Defining the scope of both the past and present hazardous waste problem, promulgating effective regulations and standards, developing management alternatives for industry, and establishing Federal and State regulatory programs are some. Virtually all interested in the hazardous waste regulatory system have voiced concerns over poor definition of the problems, delays in implementing solutions, changes in direction of the system, and uncertainties of future policies and programs.

Some delays, of course, were to be expected because of the scope of the problem. Almost all industrial activities (as well as many commercial, governmental, and institutional activities) produce some type of hazardous waste. The economic development of the United States during the 20th century has been accompanied by and, to a significant extent, based on the rapidly rising use of technology, including synthetic organic chemicals. These synthetic chemicals often pose difficult problems because of their stability, resistance to natural degradation, and sometimes hazardous properties. Every year many new chemicals are invented and put into use. Although both technology and new commercial chemicals have contributed to the growth of the Nation's industrial productivity, many associated raw materials, byproducts, and wastes require careful handling because of acidic, caustic, flammable, explosive, carcinogenic, mutagenic, or other properties. While industry has been relatively successful in limiting accidents to workers during production or industrial use, the consequences of inadequate disposal of industrial hazardous waste has emerged as a critical national problem. Hazardous wastes are highly complex, with characteristics specific to industry, process, product, or site.

Improved management of hazardous waste implies greater costs to industry and, eventually, greater costs to the public, either directly or indirectly. The alternative, however, would surely lead to higher costs in the future and unacceptable effects on human health and environment. As costs of waste management increase, there are greater economic incentives to reduce waste generation and to retrieve materials and energy of economic value from materials previously regarded as useless. However, increasing waste management costs can also increase illegal dumping of hazardous waste and increases the need for effective government enforcement programs to detect such illegal practices. The investment expended either to reduce wastes or to recover them depends on weighting the exact costs and liabilities of waste management incurred by the waste generator. Having the hazardous waste regulatory program pass from the planning to implementation stage at a time of severe national economic problems has increased the need for developing the most cost-effective approaches to waste management.

Major Issues and Uncertainties

There are two broad areas of concern to policymakers, one related to factual information and the other to policy questions. First, there are a number of uncertainties of fact in the three main areas: wastes, management facilities, and adverse effects of both on public health and environment. The formulation of effective and equitable regulations requires information on the intensity of the threats posed by wastes and on their remedies. Factual questions that have remained unanswered, and which have influenced the scope of this report, include the following:

- **How much hazardous waste is there?** What is being generated, by what industries, in what locations, and of what chemical and physical types?
- **Where is the hazardous waste?** What are the locations, amounts, and types of hazardous waste that have been managed in ways that lead, or may lead, to the unacceptable or uncontrolled release of harmful constituents into the environment?
- **What hazardous waste management facilities currently exist to receive waste?** What is their distribution by location, tech-

nology, level of control, and capacity? How much hazardous waste is being transported? How much waste is being managed on the site of the generator v. being handled in commercial or offsite facilities?

- **What are the technological alternatives for waste management?** What options exist for reducing hazard levels through treatment, for disposal to contain waste, for dispersal to render waste harmless, for cleanup of uncontrolled sites, and for reduction of the amounts of waste to be managed through process modification, end-product substitution, and recovery/recycling? To what extent are these alternatives technically feasible, cost effective, and available with or without further study? What encourages or discourages their development and use?
- **What types of monitoring techniques and programs can be used to detect releases from hazardous waste sites?** How should monitoring programs be related to types of waste, facilities, and locations? How should information from monitoring programs be used in a systematic fashion to ensure fast remedial response if necessary?
- **What are the threats from hazardous waste?** What are the specific adverse impacts on humans and ecosystems exposed to particular types of waste that may be or are released into the environment? How do waste constituents move through the environment, remain stable or degrade?

In addition to questions of fact, there is a second broad area of policy-related questions. There are difficult issues involving societal values, tradeoffs between short- and long-term solutions, costs, and equity. Given limited resources and information, what types of policies, regulations, and standards can best strike an acceptable balance between protecting the public and minimizing financial and regulatory burdens on the private and public sectors? There are difficult questions concerning risk reduction in the near term v. the transfer of risks to future generations. Moreover, policy-related issues often involve technical problems that are often difficult for any but specialized technical experts to understand. If there are important gaps and uncertainties concerning basic information, which there are, then the examination of policy issues is particularly difficult. Important policy-related issues include the following:

- **What wastes should be regulated as hazardous?** What compositions, physical states, amounts, and properties should be used to define hazardous characteristics? If some States choose to be more stringent than the Federal hazardous waste program, as they can be under RCRA, and use broader definitions or listings of hazardous waste, what problems may arise for the private sector and for formulating and implementing Federal policies? To what extent do wastes which have hazardous characteristics, but which are regulated as ordinary solid waste rather than hazardous waste, pose serious threats to the public?
- **Should the fact that different wastes pose different levels of hazard be used in regulatory programs?** Can a workable degree-of-hazard system that classifies waste (and, possibly, facilities and locations) be used to set different levels of control, standards for acceptable levels of release, and stringency of monitoring programs? Can such a system be used to limit uses of different technological alternatives, such as determining waste unsuitable for landfills, and uses for existing v. new facilities?
- **To what extent can risk assessments be used?** Can existing information on potential adverse effects on health and environment be used in risk assessments? Should costs of management alternatives be used with evaluation of risks? If the information needed for such analyses is unavailable or unreliable, would requiring such analyses be effective or only delay action?
- **Do current regulations permit the market to operate in ways that ensure the full internalization of costs for alternative management approaches?** Does the current system provide incentives for development of alternatives that may provide greater

protection to the public? Are the costs for long-term monitoring of facilities containing hazardous waste (that may possibly remain hazardous forever) and the possible costs for remedial action being properly accounted for in today's waste management cost structures?

- **To what extent is public opposition to new hazardous waste facilities justified?** Is this opposition commensurate with what is now known about the risks involved? Would better information on wastes, technologies, facilities, and potential effects reduce public opposition? Are the processes, including public participation, and technical criteria used for siting new facilities appropriate?
- **What criteria can be used for determining the extent of cleanup of an uncontrolled site?** Is there sufficient attention being given to all the alternatives and to the relative advantages and disadvantages for both the short and long terms? Do current policies provide an incentive for alternatives that have low capital cost, but high operating and maintenance costs?
- **What are the effects of having many different laws that influence hazardous waste management and regulation?** Is it efficient to have different laws, administered by different agencies or different groups within an agency, to govern different categories of technological alternatives, such as ocean dumping, injection in deep wells, and other facilities on the land? Do clean air and water regulations adequately address the types of constituents likely to be released from hazardous waste? Does the law concerned with production of toxic chemicals provide an appropriate means to reduce the generation of toxic waste?
- **To what extent do current programs promote development of new alternatives to more traditional environmental regulations?** Is the current use of financial liability requirements likely to lead to more efficient self-regulation in industry? Are there economic incentives that would be more effective than traditional regulations in fostering improved management?
- **What is the proper and most efficient balance of responsibilities between the Federal and State programs?** To what extent can State programs be equivalent and consistent with the Federal program, and yet responsive to varying State needs and circumstances? Do the States have sufficient financial resources to carry out their increasing responsibilities? Are the States being given a fair opportunity to shape the policies that they are being asked to implement? Is the Federal program providing the type and extent of technical information useful to all States?

These lists of questions and issues are by no means complete. They serve to illustrate the scope of present-day concerns about the present and future direction of hazardous waste policies. Moreover, these questions indicate the orientation of the present study, which is concerned primarily with examining Federal programs and alternatives that can reduce the risks of hazardous waste management in an expeditious and cost-effective manner.

Objective, Scope, and Structure of the Assessment

Objective and Scope

RCRA as amended requires the Environmental Protection Agency (EPA) to issue and enforce regulations governing the disposal of solid and hazardous waste. It allows the States, if they choose, to assume primary regulatory and enforcement responsibility for solid waste in general, and for the subclass generally termed hazardous waste. Financial assistance to States, municipalities, and regional authorities is authorized by RCRA in order to facilitate planning, management, and standard setting required for authorization to be shifted from the Federal to the State level.

The magnitude of the task facing EPA was generally recognized to be great. Six years after passage of RCRA, however, a consensus has also emerged, particularly as Congress considered reauthorizing RCRA in 1982, that progress has been slow. Both Federal and State regulatory frameworks for dealing with solid and hazardous waste remain uncompleted. Delays and uncertainties concerning the regulation of waste have created problems for the industrial sector, for both generators and disposers of waste. Public concern has not abated.

CERCLA provides a funding mechanism for corrective actions taken at a variety of inoperative or abandoned waste sites and for cleaning up accidental releases of hazardous materials. Here too there is general recognition that progress has been slow.

This assessment by OTA is designed to assist Congress in its examination of appropriate measures to prevent harm from those solid wastes defined as hazardous. As requested by Congress, **this assessment focuses on:**

- analysis of the technologies that can improve hazardous waste management through:
  —reduction of the volume or hazard level of waste generated;
  —better management of the risks associated with waste treatment and disposal; and
  —the cleanup of uncontrolled waste sites;
- analysis of the potential benefits and costs of a framework based on scientific criteria to judge the relative degree of hazard of wastes and risks from management facilities; and
- evaluation of current regulatory programs, particularly with regard to technical information and issues.

It should be understood that **this is an analytical study to provide a basis for policy discussion and examination of legislative options by Congress, and not an attempt to write new or revise existing regulations for the executive branch or for the States.** However, Federal and State roles in hazardous management for both the near and long term are considered.

The scope of this assessment is limited in the following ways:

1. Within the definition of solid waste, which includes a range from household discards and municipal sewage to highly radioactive waste, **the focus of this study is nonnuclear industrial hazardous waste associated with subtitle C of RCRA.** No attempt has been made to analyze the generation and management of hazardous waste at Federal facilities, although it is generally understood that very large amounts of waste which are similar to industrial hazardous waste are generated in Federal facilities, including numerous Department of Defense installations.
2. The primary emphasis of this study is the management of waste in existing or future facilities, although the problems associated with closed facilities and past practices of abandoned facilities as considered in CERCLA are dealt with to some extent.
3. This analysis is concerned with examining the procedures for assessing the nature, intensity, and monitoring of adverse effects on health and the environment resulting from release of hazardous waste or their constituents into the air, land, or water. Major attention, however, is not given to substantiating, documenting, or critically evaluating the many data associated with real or potential adverse impacts.
4. The issues and technical problems associated with transportation and accidental release of hazardous waste are not considered, except to the extent that some technical and policy approaches may help to minimize transport of waste.
5. Although technical compliance with regulations is an important area of concern, strictly administrative and legal enforcement activities associated with regulations are not analyzed in any major way; however, their importance is found to be critical.

Public opposition to the siting of new hazardous waste facilities has been widespread in recent years. Means for dealing with public opposition to siting and public participation in State and local decisionmaking are briefly examined. The role of the Federal Government in siting of new hazardous waste facilities is now minimal, but options for more involvement are discussed.

Methodology and Structure of the Report

In preparing this assessment, OTA has utilized a number of means to obtain appropriate information without, however, attempting major acquisitions of new data or complete inventories of data. Instead, OTA used and performed critical analyses of available data bases, cooperated with the States in some limited surveys for critical information, and used a case study approach in a number of instances to provide a representative basis for analysis.

Other than chapter 1, the summary of the entire report, and this chapter, there are five additional chapters, briefly described below.

Chapter 3 presents eight goals for evaluating policy options, and five policy options for Congress to consider. The first option is a continuation of the current program. The second is based on a series of near-term changes in the current regulatory system, probably through amendments to RCRA. The third option is to offer Federal economic incentives for alternatives to waste disposal or dispersal in the environment. The fourth option calls for a study to develop a waste and facility classification approach for a comprehensive risk management and regulatory framework. The fifth option is an integration of the many Federal environmental programs that affect hazardous waste management and regulation. The five options, for the most part, are not mutually exclusive, but can be viewed as a series of complementary steps over a period of time. All options are analyzed for their benefits relative to the eight policy goals, and for the costs and problems associated with their implementation. Additionally, four scenarios are used to illustrate how several options may be combined.

Chapter 4 analyzes the available information on hazardous waste generation and treatment and disposal facilities. The linkage between information and the complex nature of the national hazardous waste problem is examined. An analysis of the current data base for hazardous waste is given. The discussion examines information needs of parties concerned with hazardous waste, and the consequences of having incomplete or unreliable information. This material forms an important basis for the other chapters, particularly with regard to data limitations that sometimes make policy-oriented analyses less quantitative than desirable.

Chapter 5 reviews the broad range of technologies now available and assesses those likely to be developed for hazardous waste management. A hierarchy is used to present management strategies, ranging from waste or risk reduction to disposal or dispersal in the biosphere. Technologies are compared and examined for suitability to particular wastes, their costs, and the technical issues relevant to regulation. The use of the oceans for waste disposal or dispersal, and the cleanup of uncontrolled sites are also discussed.

Chapter 6 examines "state-of-the- art" information and theory on the assessment and management of risks, and the diversity of current views on these issue areas. The primary purpose of chapter 6 is to provide a base for evaluation of current and alternative policies by defining several technical issues that policies are expected to address, including monitoring and siting of facilities.

In chapter 7 the current hazard management and regulatory system at both the Federal and State levels is reviewed and analyzed. Another purpose of this chapter is to assess the extent to which the current system is addressing the issues discussed in chapter 6, and at what costs. The Federal and State roles and programs are reviewed and discussed separately. A number of problems related to implementation of the current regulations are also examined.

CHAPTER 3
Policy Options

Introduction

This chapter presents for congressional examination five policy options for the Federal hazardous waste program. Rather than mere control of potential threats, the primary problem facing the current program has become one of preventing impending crisis situations, which present sudden problems of large proportions. For example, aquifers serving as sources of drinking water have recently been discovered to be contaminated from hazardous waste. Little reliable information concerning the likelihood of future incidents is available—and, as this study indicates, there is a lack of general confidence that current regulations will prevent future incidents. However, there is general agreement that it is far more costly to respond to such adverse effects than to prevent them.

The five policy options, which are evaluated in terms of certain overall goals, are as follows:

- Option I: Continuation of the Current Program.
- Option II: A More Comprehensive and Nationally Consistent RCRA Program.
- Option III: Use of Economic Incentives for Alternatives to Disposal and Dispersal of Hazardous Waste.
- Option IV: Development and Potential Use of a Hazard Classification Framework.
- Option V: Planning for Greater Integration of Environmental Protection Programs.

With the exception of the first, maintaining the current direction of the evolving regulatory program, the other four policy options, taken together, can be viewed as a series of complementary changes to improve and reorient the current program. Four scenarios are presented to indicate how several options may be combined. For example, one scenario (a combination of options I and III) responds both to the belief that the current regulatory program, will prove to be effective and to the need to promote greater use of alternatives to land disposal.

One general constraint on this consideration of policy options is that analysis has been less quantitative than desired because of a lack of complete and reliable data. Detailed analyses of the costs and benefits of particular options require extensive data concerning wastes, facilities and technologies, and potential adverse impacts on health and the environment. This information is generally unavailable or insufficient. A discussion of available data is contained in chapter 4.

Moreover, the objectives and limitations of this study (described in ch. 2) should be kept in mind when considering these policy options. The focus of this assessment has been on technologies and management strategies; the policy options address problems and issues associated primarily with these two areas. Although this study does not focus on strictly administrative and procedural issues, such as enforcement of regulations, permitting of facilities, or authorization of State programs, OTA examined these problems when they were closely connected to the technical components of the regulatory program.

The General Accounting Office, among others, has focused on several administrative aspects, including the critical area of enforcement, in a number of reports to Congress. Most recently, a congressional study has documented critical concerns in the enforcement of both the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental, Response, Compensation, and Liability Act of 1980 (CERCLA) statutes and regulations.[1] There are indications of an increased administrative reliance on voluntary compliance and settlements with responsible parties, and of substantial reductions in funding for enforcement activities. OTA's study of technical issues and problems, such as the effectiveness of pollution control regulations or the exemption of waste from RCRA regulation, cannot substitute for congressional examination of the administration of the Federal program. **The policy actions discussed below, regardless of their merits, are not likely to produce favorable results unless enforcement is effective.**

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[1] U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Oversight and Investigations, report on enforcement of hazardous and toxic substances regulations during fiscal year 1982, October 1982.

Common Goals for Policy Options

The current Federal hazardous waste program presents a dilemma. There is a sense of urgency and impatience, derived from 6 years of difficulties in dealing with an extremely broad and complex set of issues. Suggesting changes in Federal policies, therefore, creates concerns over the possibility of still more delays. Those who support the current Federal program (both RCRA and CERCLA) believe there is a need to allow more time before conclusions concerning effectiveness are drawn and possibly disruptive changes are made. On the other hand, there is also a widespread belief that current programs could be made more technically, economically, and socially effective. Waiting for the determination of the current program's effectiveness, it is argued, may lead to the development of outright crises, such as widespread ground water contamination. There is consensus that we are now acting more effectively than in the past to protect the public from improper hazardous waste management. But there is also considerable evidence (concerning, e.g., the technical limitations and uncertainties of land disposal techniques) that we may be acting in ways which are too temporary in nature, leading to greater public risks in the future, and increased ultimate costs to industry, the government, and the public.

This dilemma must be considered in the context of reduced funds for government programs. Such conditions may prompt industry, State and Federal Governments, and the public to avoid additional costs associated with a cleaner environment in order to cope with economic difficulties. Options that defer costs, that do not jeopardize current industrial activities, that shift risks to the future, may become more attractive than in the past. Such tradeoffs pose formidable choices for policymakers, made more difficult by current uncertainties concerning the effectiveness of laws and programs not yet fully implemented.

It is therefore helpful to define specific goals for policy options for purposes of comparison and evaluation. Eight such goals for any practical congressional option are presented below. These goals will be used later to evaluate each of the policy options.

GOAL 1

Improve protection of health and the environment without undue delays and uncertainties by:

- **reducing the magnitude and hazardous nature of potential releases of waste constituents from all types of waste generation and management facilities,**
- **improving monitoring programs to quickly detect such releases, and**
- **improving corrective actions to mitigate releases.**

Many of the analytical results of chapters 5, 6, and 7 support the need for improving the level of protection of human health and the environment by concentrating on technical, as well as administrative, matters. It would be desirable to achieve this goal without causing undue delays in the program that could have counterproductive effects leading to unacceptable releases before improved policies and programs became effective, and would seriously erode public confidence. It should be clearly understood that the current Federal hazardous waste program offers unequivocal improvements over the virtual absence of regulations that existed previously.

GOAL 2

Expand the universe of federally regulated hazardous waste, recognizing that different levels of regulation under RCRA may be appropriate and desirable.

During the inception of the RCRA program, it was reasonable to limit the scope of regulated wastes. It has become increasingly clear, however, that the exemption of hazardous waste from Federal regulation has not been well correlated with the degree of hazard of the waste. Nonregulated (under subtitle C of RCRA) hazardous waste may constitute very large volumes (see ch. 4) and may be legally disposed of in ways that threaten health and the environment.

There is no way of knowing with certainty whether the current regulatory program is directed at those wastes representing the greatest or most immediate threats. It is probable that both underregulation and overregulation are occurring. A more inclusive approach could address problems created by disposing of unregulated hazardous waste in sanitary landfills. Furthermore, careful definition of specific levels of increased control could reduce the amount of effort currently expended in attempts to have various wastes delisted.

Policy options should be evaluated with regard to their effect on bringing those wastes that are hazardous to any degree into the regulatory system **in appropriate ways, if only for reporting and notification for low-hazard waste.** Policy options differ regarding the determination and recognition of varying levels of hazard (assessment, e.g., may be only qualitative) and in corresponding assignments of appropriate levels of regulatory control.

More complete regulatory coverage of hazardous waste would likely improve public confidence in the Federal program, thus contributing to the achievement of goal 8. Such control could lessen concern that wastes regulated on State initiative may receive low priority. Furthermore, there would be less likelihood of new uncontrolled waste sites requiring large Federal expenditures in the future.

A more inclusive system would encourage the development of new waste management technologies (see ch. 5) for an increased and more stable commercial market (goal 3). It would also facilitate the development of improved data bases (goal 4).

GOAL 3

Encourage development and use of technological alternatives to land disposal (including land and ocean dispersal), such as waste reduction and treatment, to reduce risks resulting from release of hazardous waste constituents into the environment.

This policy goal reflects a primary strategy of minimizing releases of hazardous constituents by initially avoiding the placement of hazardous waste in the environment. There are approaches for the control of risks involved in disposal and dispersal. However, those desiring to use such options should demonstrate that acceptable levels of releases are achieved and maintained for the particular waste so managed.

Chapter 5 discusses various technologies and the different levels of certainty and reliability they provide with regard to control of releases into the environment. **Disposal and dispersal of hazardous waste in the environment involve too many uncertainties concerning acceptable levels of releases. Cleanup of uncontrolled sites involves unacceptable levels of technical difficulty, cost, and uncertainty.** Discussions and analyses of the current regulatory programs in chapter 7 also indicate that the use of disposal and dispersal approaches should be minimized. Ground water contamination is a primary threat. A U.S. Geological Survey (USGS) report supports these concerns:

> Present technology is not adequate to develop regulations to protect the public from hazardous waste contamination in a cost effective manner. Major technical questions are yet to be answered regarding the behavior of specific wastes under different hydrogeologic conditions and on the safety, suitability, and economics of restoration and disposal methods.[3]

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[3] "Management Implementation Plan, FY 1984," for Toxic Waste-Ground-Water Contamination (Washington, D.C.: U.S. Geological Survey, Sept. 27, 1983).

There will always be questions concerning the definition and determination of acceptable risks. It is clear, however, that the safest course is to promote the use of waste reduction and treatment alternatives as much as is possible and practicable. In so doing, costs must be **appropriately** taken into account. RCRA does not mandate a balancing of costs and risks as a means of determining what should be done to protect the public good. Instead, a cost-effectiveness approach is indicated, by which the management alternative is chosen that, for the least cost, adequately protects human health and the environment.

GOAL 4

Improve and expand data and information on hazardous wastes, facilities, and their effects which are necessary for more reliable risk assessments and for the implementation of RCRA and CERCLA by both the Environmental Protection Agency (EPA) and the States.

Complete information on any major national problem is hardly ever attainable, in order to improve waste management and risk assessment, better information is needed on the following:

- The level of generation of all hazardous waste, if federally regulated as such, in the States and for the Nation as a whole, as a function of chemical and physical types, and origin.
- The numbers and capacities of active waste facilities, both onsite and offsite (or commercial), particularly as a function of technology type, types of waste managed, and levels of control for release of waste constituents into the environment.
- The number and location of inactive waste management facilities or open dump sites, and the types and amounts of wastes associated with these sites.
- The range of potential health and environmental effects as a function of waste type, management technology and facility, and type of location.

A major finding of chapter 4 was that the currently available data and information resources concerning hazardous waste, technologies and facilities, and adverse effects are incomplete, inconsistent, and unreliable in various important respects. This does not imply that the data and information currently available are so inadequate that implementation of the current program or its modifications is not possible. With regard to evaluation, however, EPA has noted that its " 'managing for results' program for evaluating the effectiveness of its environmental programs may require better and more timely environmental data from the States . . ."[3]

Several important benefits would result from consequent improvements of data. The facilitation of hazard and risk assessments, as discussed in chapters 6 and 7, would be of particular importance. Also, specific technical criteria could be incorporated into RCRA regulations and into certain elements of CERCLA, particularly the National Contingency Plan and the determination of the extent of cleanup at uncontrolled sites (see ch. 5). The current absence of specific technical criteria in regulations may be based on a reluctance to present such criteria based on available information, recognizing that changes are inevitable as improved data are obtained. Management systems cannot be **evaluated as to effectiveness** without adequate data and information bases.

It is important to recognize the problems which EPA has faced thus far in this area. The large burden of initiating the RCRA program, a lack of consistent congressional and administrative priorities, the difficulty of obtaining data, the large amounts of data required, and the continuing finding that the data obtained early in the program lacked accuracy are representative. Some mandates for obtaining data and information were given in the RCRA and CERCLA legislation. These, however, suffer from a lack of coordination, completeness, and expeditious implementation by EPA. Also a greater understanding of the limits of the National Manifest System is needed; it deals only with waste transported offsite, which vary markedly among States and comprise only a fraction (usually 10 to 30 percent) of the total amount of waste generated. A greater appreciation is needed for the value of regular reports from all waste generators rather than surveys based only on samples which EPA has decided to use.[4] Also needed is greater understanding that data require continued updating and verification, with ongoing analyses, and procedures to facilitate public access to both the data and analyses. Furthermore, coordination of the information collected under the RCRA and CERCLA programs, in other major programs in EPA, and in other Federal efforts could be improved. Finally, it is important to acknowledge that many data need to be safeguarded to protect company confidentiality and proprietary rights, and that a balance must be struck between this need and the right of the public to have access to data and information.

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[3] Lewis S. W. Crampton, EPA Issue Papers, September 1982.

GOAL 5

Improve and expand participation in RCRA and CERCLA by the States through better definition, implementation, and support of both Federal and State responsibilities.

It is essential that policy options be evaluated as to their definition of the role of the States and EPA, and how they might improve and expand participation by the States. It makes no sense whatsoever to shift responsibilities to the States unless there is a corresponding improvement in their resources (financial, technical, and human) to carry out those increased responsibilities. A recent analysis of these responsibilities concluded that:

> EPA lacks the administrative capacity and knowledge of local conditions necessary to implement RCRA by itself; states lack the research capacity to develop complex regulations. Consequently, EPA and the states must share responsibility for implementing the statute under the state programs provisions. Sharing responsibility means tolerating differences. In evaluating state applications for final authorization under RCRA, EPA should construe the requirement that state programs be consistent with and equivalent to the Federal program. This will allow states the flexibility to design their programs to reflect local conditions (and) to be more stringent than the federal program. Sharing responsibility also means fulfilling obligations. EPA has been inexcusably slow in promulgating final RCRA regulations. EPA has made it difficult for states to develop hazardous waste programs; states have no clear idea what differences between state and federal programs will be allowed or even what the federal program will look like."[5]

It is important to view RCRA and CERCLA as two components of a joint Federal-State program. It was not a goal of this assessment to examine the problems and issues associated with the delegation of RCRA program responsibility to the States or with the role of the States in CERCLA. However, during the course of this study it often became necessary to examine State actions and concerns, particularly as they relate to scientific and technological factors. For example, as discussed in chapter 4, the varying ways in which the States have decided which hazardous wastes to regulate and whether, and how, to exempt small generators is quite important to an understanding of the scope of the hazardous waste problem. The choice of sites and remediation technologies under CERCLA, as discussed in chapters 5 and 7, is also directly related to Federal-State interactions and vitally affects risks to the public.

The Federal hazardous waste program has had many positive effects on State programs, often raising standards, prompting regulatory coverage where none previously existed, providing technical information, and helping to streamline State administration of hazardous waste regulations which are sometimes split among several State groups. However, this study, along with hearings during 1982 concerning congressional oversight and RCRA reauthorization, has made it apparent that there are serious problems in Federal-State relationships.

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[4] EPA's policy on annual reporting requirements has shifted several times, but as of a notice in the Federal Register on Oct. 12, 1982, the annual reporting requirement for waste generators and facilities has been replaced by a nationwide biennial survey by EPA directly with waste handlers. The States have raised a number of objections to this policy, including a conflict with congressional intent (sec. 3006 of RCRA), bypassing authorized States who have the responsibility for such collection, and lack of timely improvements in the complete national data base. Letter from Richard A. Valentinetti, President, Association of State and Territorial Solid Waste Management Officials, Nov. 4, 1982, to Rita LaVelle, Assistant Administrator, Environmental Protection Agency.

[5] Karen L. Florini, "Issues of Federalism in Hazardous Waste Control: Cooperation or Confusion," *Harvard Environmental Law Review*, vol. 6, 1982, pp. 307-337.

Although the States do not have to accept program responsibility, State-run programs can be made more attractive by provision of adequate Federal funding and efficient administration of RCRA and CERCLA by EPA.[*] The findings of chapter 7 (concerning problems of the current Federal program) support the contention of many States that they must exercise their right under RCRA to be more stringent than the Federal program. The Federal program, they argue, should be viewed, as intended by Congress, as a regulatory "floor" rather than as a "ceiling." RCRA limits variations among State programs by making final authorization contingent on State programs being "equivalent to" and "consistent with" the Federal program. However, it appears that EPA may frequently be authorizing State programs that are identical to the Federal program (a "mirror" approach) which States sometimes view as too lax. The States also maintain that the legislative use of the word "program," rather than "regulations," supports their position that equivalency and consistency should be based primarily on the effectiveness of State programs rather than on statutes and regulations themselves.[6]

There are sound technical reasons why some variations in standards and regulations may be appropriate among the States. Differences in hydrogeologic conditions, climatic conditions, population distributions, public attitudes toward acceptable risks, types of industries, and types of waste management facilities already in place are such factors.

The States have much to offer to the national hazardous waste program. There is considerably more practical experience at the State level (although actual data and technological expertise may be lacking in many cases), more intimate knowledge of what exactly is taking place in waste generation and management, and more experience with interpretation and enforcement of waste regulations than at the Federal level. A number of States have considerable experience in permitting of facilities under State statutes, whereas Federal permitting has barely begun.

Furthermore, many innovative programs exist at the State level, but the extent to which these could be advantageously transferred to the Federal level, or to other States, has been little studied. Examples of such innovations include:

- degree-of-hazard approaches to varying levels of appropriate waste regulation, which sometimes conflict with the Federal "floor" approach;
- plans to prohibit the use of landfills for particularly hazardous waste;
- prohibition of the disposal of bulk, and in some States even containerized, liquid waste in landfills;
- fee systems to shift private sector choices toward waste reduction efforts and away from the use of landfills;
- direct incentives for alternatives to land disposal;
- some regulation of facilities that recycle wastes;
- development of workable siting criteria and plans;
- onsite inspectors for waste facilities;
- delegation of decisionmaking authority to county government; and
- extensive, specific provisions for involving the public in regulatory decisionmaking.

If Congress attempts to detail the Federal and State responsibilities under RCRA, various issues require clarification. For example, States are often asked to enforce standards, regulations, and policies that they believe are not in the public interest, and that they believe to be incorrect, misdirected, or unenforceable. Congress may wish to consider modifying or clarifying administrative regulatory procedures, such as the Federal Advisory Committee Act (FACA), so as to involve States differently than the manner in which other interested parties now participate in regulatory development and rulemaking. States could contribute actively, rather than reactively, with Federal recognition that the States have a responsibility to participate in policy formulation, and not merely implementation of federally mandated policies. A recent report to EPA by the Association of State and Territorial Solid Waste Management Officials (ASTSWMO) addresses this problem:

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[*] It should be noted that although most view the position of the States as necessitating receiving RCRA authorization from EPA in order to have a hazardous waste program responsive to public concerns, it is possible for States to allow EPA to administer the Federal program within their States and to also administer their own State program as a separate activity. This would place burdens on the regulated community, but might appear attractive to States if Federal support, both financial and technical, were deemed insufficient, or if the Federal program were deemed too lax.

[6] Letter from Richard A. Valentinetti, President, Association of State and Territorial Solid Waste Management Officials to Thomas W. Curtis, National Governors' Association, Nov. 15, 1982.

> Despite both the congressional mandate for EPA to seek consultation from the States in the regulatory development process and the current Administration's proclivity toward supporting the New Federalism concept, EPA has been protected from outside State opinion. EPA's use of the FACA law and of the ex parte rule have provided questionable rationales for denying State intervention in the regulatory decision-making process. Reinterpretation of ASTSWMO members (who are State government employees) as EPA principals would also attempt to eliminate FACA/ex parte restrictions so that State participation could occur at any point during the entire regulatory development process. Information flow from EPA to ASTSWMO member States has been hampered . . . by the EPA policy to not include ASTSWMO in Federal planning and strategy activities.[7]

One conflict concerns the choice of remedial technologies to clean up uncontrolled sites under CERCLA (see chs. 5 and 7). The Federal bias is toward using low capital or initial cost approaches, for which the Federal program pays 90 percent (or 50 percent in the case of State or municipally owned sites), and that may have high, and highly uncertain, operating and maintenance costs, which the States pay entirely. The States favor approaches that are higher in initial costs, but that deal more permanently with the problems of the sites and are likely to have relatively low operating and maintenance costs. For example, in many cases, waste in uncontrolled sites are transferred to another land disposal site, rather than being treated or destroyed.

Another problem associated with CERCLA concerns funding. Presently no continuing Federal support is provided to State activities for early identification and evaluation of uncontrolled sites for possible CERCLA funding, including the extensive effort required to obtain data to rank sites for the National Priority List, searches for responsible parties, analysis of possible remediation approaches, responding to EPA directives, and support of EPA's enforcement activities. A recent survey of States indicates that about 10 percent of the RCRA grants to the States are being used for these CERCLA activities.[8]

Technical aspects of State programs could be improved by Federal requirements for reliable technical information and guidance. If there is insufficient data from waste generators, States may have difficulty determining whether particular wastes are being managed properly, or whether they are being handled illegally. This is a problem with onsite generation and management currently outside the Federal manifest system, unless there is sufficient reporting requirements to obtain detailed information.

The role of the States in data acquisition is also unclear. States could participate more directly in the critical task of improving the data base (as discussed above) by serving as direct sources of information, in contrast to the current Federal practice of using contractors on an ad hoc basis. Such contractors are often only costly intermediaries, doing little else than contacting the States for information, with too little attention given to organizing data into a common format, and to verifying the quality and accuracy of the data. It would be useful to have a clearer policy defining the Federal and State roles with regard to acquiring and maintaining data bases. **It appears appropriate to consider the States to have the prime responsibility for data, with EPA serving as the institution ensuring consistent definitions, providing uniform formats for data acquisition, acting to validate data, and serving as a central compiler of data obtained from the States.**

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[7] Annual report by ASTSWMO to EPA for fiscal year 1982, October 1982.

[8] Of the 30 States providing information, 23 used RCRA funds in fiscal year 1982 for CERCLA activities, these States accounted for 46 of the 115 sites on the original interim Superfund priority list. Personal communication from the Association of State and Territorial Solid Waste Management Officials, November 1982.

RCRA grants to the State programs should reflect the large and costly tasks of collecting information and making it useful through analysis, data processing, and computer retrieval (see ch. 4). OTA studies show that, in a number of States, reports and manifest forms containing useful data remain unexamined and unprocessed because of a lack of resources, such as lack of computer facilities.[9] Routine State activities often require complete information bases, from which surveys based on statistical samples can have only limited use. These samples do not provide data on specific facilities requiring inspection and permitting that State officials may not be aware of. Furthermore, statistical results for the Nation do not reveal unique State or regional conditions.

GOAL 6

Moderate the inevitable increases in the costs of Federal and State program administration and regulatory compliance by industry and minimize costs associated with site remediation and compensation for further damages to health and the environment which may result from current practices that could be improved.

As discussed in chapter 7, the private sector annual costs of complying with RCRA and CERCLA are now estimated to be in the range of $4 billion to $5 billion, and total Federal and State costs are about $200 million annually. With the RCRA and CERCLA programs just now in their early phase of implementation, increased costs are to be expected. Private sector costs with the current Federal-State program are estimated to increase to about $12 billion (in 1981 dollars) in 1990 (see ch. 7). Even a modest improvement in the efficiency of the Federal and State programs could save many millions of dollars. One of the greatest uncertainties concerns the extent to which present government policies and private sector management choices will result in the creation of future uncontrolled sites, with consequent releases of hazardous constituents, costly cleanup actions, and expensive liability suits. It is important, therefore, to evaluate policy options for their ability to reduce long-term costs for both government and the private sector.

GOAL 7

Reduce risks transferred to the future, whether several years or to future generations, and reduce costs of waste management that are externalized and shifted to society in general.

There should be minimal transfer of risks and costs to the future, whether it be years or decades, on general grounds of equity. Furthermore, deferrals of optimal solutions inevitably lead to a compounding of the technical nature of the problem, to marked increases in costs, and sometimes to the prevention of any practical solution (as, e.g., in the contamination of a large underground aquifer serving as a major source of drinking water). As discussed above, and in chapters 5 and 6, it must be assumed that use of the environment for disposal and dispersal of various wastes now constitutes a threat for the future because of the high probability of releases of hazardous constituents into the environment.

There are two basic reasons for fully internalizing waste management costs, including the possibility of future remedial actions and compensation for damages to human health and the environment. First, on the basis of equity, it is proper that those persons most responsible for waste generation should pay for proper management, including those choosing to consume products or use services requiring the generation of hazardous waste. Second, if the management alternatives most protective of the public good are to be promoted, then it is reasonable to penalize those alternatives providing lower levels of protection.

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[9] Personal communication from the Association of State and Territorial Solid Waste Management Officials.

GOAL 8

Reduce public concerns over the siting of hazardous waste management facilities by improved implementation and enforcement of government programs.

It is obvious that hazardous waste will continue to be generated. Even with reductions in some waste generation resulting from the current regulatory program and greater concerns with future liabilities, there will probably be an overall increase in hazardous waste generation if economic activity increases. Such increases may require new facilities. If there is a shift away from land disposal as the dominant management choice, new treatment facilities will be required. It is also possible that more land disposal facilities may be required, depending on how the current regulatory program (particularly permitting) affects existing facilities, on the level of success in shifting to alternative management options, and on the level of future waste generation. Public concern over permitting existing facilities and siting new ones, therefore, poses a serious problem for improving hazardous waste management.

Public concern over the need for, and siting of, new waste management facilities can be addressed through both technical and institutional approaches. Technical approaches include improved public understanding of alternative management strategies, effective technology options, future capacity needs, varying hazard levels for wastes and facilities, health and environmental effects, hydrogeologic siting criteria, and present and future costs. As discussed in chapter 6, there is no assurance that better information will remove public opposition to siting of new waste facilities, but there is hope that public confidence in government policies can be improved. With increased public confidence, public concerns and private sector needs may be better reconciled.

Five Policy Options

OTA has defined five options that would address both short- and long-term needs and problems of the Federal hazardous waste program. As indicated earlier, with the exception of the status quo option, the remaining options can be viewed as a complementary series of changes that would improve and reorient the program over time. The five options are stated below, followed by a more detailed discussion of each.

- **Option I: Continuation of the Current Program.**—The current program, together with certain planned changes, is maintained.
- **Option II: A More Comprehensive and Nationally Consistent RCRA Program.**—Near-term changes in regulations can be made by making amendments to RCRA. These changes include a redefinition of which wastes are regulated and to what extent, a shift toward limiting land disposal, the introduction of limited class permits, and the greater use of specific technical criteria in regulations. These changes would not alter the structure of the current program, but, they would significantly impact the regulated community.
- **Option III: Use of Economic Incentives for Alternatives to Disposal and Dispersal.**—This is a near-term program to reduce the use of disposal and dispersal approaches to waste management by providing direct economic incentives for alternatives such as waste reduction, recycling, and treatment. Three key components of a comprehensive incentive program are a fee system on hazardous wastes generated, a means to address capital investment needs, and assistance for research and development (R&D). Such a program could be implemented by either amendment to RCRA or CERCLA or by a new statute.

- **Option IV: Development and Potential Use of a Hazard Classification Framework.**—This is a longer term program to first study and then possibly adopt some type of waste and facility hazard classification as a systematic framework for regulatory decisionmaking. Such a system can be used for setting priorities, setting monitoring requirements, and determining the appropriate level and type of regulation, including performance standards. It could be implemented by amendment to RCRA, with the first phase consisting of a study to further examine and better quantify potential benefits, as well as feasibility, design, and implementation problems.
- **Option V: Planning for Integration of Environmental Protection Programs.**—This would be a long-term effort, beginning with a study, to integrate existing environmental programs. Major goals would be the elimination of gaps, overlaps, and inconsistencies in regulatory coverage, and the prevention of RCRA permitting of facilities that improperly manage hazardous waste regulated under other acts. The first phase would consist of a major examination of how such integration could be achieved and the presentation of a plan for integration, including an analysis of the need for statutory changes. This option is consistent with section 1006 of RCRA which directs such integration by the EPA Administrator, but which does not require a submission of a plan to Congress nor a specific time for such integration. In the second phase, Congress would examine the plan and consider necessary statutory changes.

Option I
Continuation of Current Program

This option assumes that the mandates of both RCRA and CERCLA may be met by the current Federal hazardous waste program. It should be recognized that the present program is not static. EPA has indicated several plans for changes and improvements in the near term.[10]

Unlike the other policy options, no unusual implementation problems and costs are associated with this "status quo" option. Criticisms of the option are based on perceptions of current problems, or point to unacceptable risks and costs involved in waiting for the program to "prove itself." In the following discussion, the current program, the "status quo" option, is evaluated in terms of the eight goals presented earlier.

GOAL 1

Improve protection of human health and the environment without undue delays and uncertainties.

Analysis of the benefits of the "status quo" option relative to this goal clearly presents the conflicts between short- and long-term evaluation. This option, by definition, involves no delays or revisions of the current program, and the current program is certainly providing increased protection than existed previously. Final regulations have been promulgated and permitting is beginning. State programs are being authorized. CERCLA-funded cleanups of uncontrolled sites are taking place. Enforcement actions for both RCRA and CERCLA are occurring. Better information is being obtained.

However, to the extent that the level of protection is lower than it could be, the benefit from this option is less than it could be. On balance, this option is considered to offer a moderate benefit. Criticisms of the current program have been shaped by past delays and changes in direction and primarily focus on: 1) the **speed and extent** of its acknowledged advantages relative to what existed previously, and 2) ambiguous signals given to decisionmakers in the regulated community. Uncertainties over the program's eventual effectiveness are related to the following:

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[10] The primary source for future directions of EPA's current program is a letter dated Sept. 7, 1982, from Rita M. Lavelle, Assistant Administrator for Solid Waste and Emergency Response, EPA, to the Honorable Thomas P. O'Neill, Jr., Speaker of the House of Representatives.

1. continued litigation, judicial decisions, or negotiated settlements, that result in changes in policies and regulations;
2. negative public response to new regulations; and
3. adverse impacts on health or environment that were otherwise avoidable, or that clearly would not be prevented by the present program even if it had been in place earlier.

These uncertainties, and other factors detracting from the benefits of the current program, are discussed further in the consideration of the remaining seven management goals.

GOAL 2

Expand the kinds of federally regulated hazardous waste.

This option offers a minor benefit. There is no systematic program or policy to substantially remove current exemptions or to close gaps in regulatory coverage. But certain exemptions are being dealt with by EPA on an ad hoc basis.

The current RCRA subtitle C program regulates only a portion of the Nation's solid wastes that have hazardous characteristics. This situation has resulted primarily from both congressional and administrative exemptions granted to facilitate the initiation of the national program. There are also established procedures for removing wastes from the RCRA lists. The exemption of small generators of hazardous wastes is being examined, and may be refined with regard to both the level of waste required for exemption and the types of waste generated. Similarly, EPA has stated its intention of proposing regulations in 1983 covering the burning of hazardous waste as fuels, now currently exempt from RCRA coverage. For the most part, however, the major exemptions existing in RCRA as mandated by Congress would remain, and those areas being reviewed by EPA may remain unchanged for some years.

With regard to **how** wastes are regulated, there are for example limited, missing, or uncertain restrictions on land disposal of certain types of waste that present well-known risks. Such wastes include:

1. liquid wastes in landfills;
2. particularly persistent, mobile, and toxic wastes in landfills and surface impoundments; and
3. volatile wastes in surface impoundments; and
4. wastes that have the ability to degrade the liners in landfills and surface impoundments.

EPA has indicated that studies are underway to determine the basis for prohibiting land disposal of hazardous waste which are highly toxic, persistent, and mobile where alternative treatment or recovery technologies are reasonably available. Also, requirements for monitoring and control of volatile organic compounds in land disposal facilities are being studied.

Furthermore, the regulation of industrial hazardous waste going into municipal water treatment systems or requiring pretreatment under the Clean Water Act (CWA) has not yet been fully implemented. There is some evidence that regulation of hazardous waste under CWA, but not under RCRA, may lead to the release of hazardous substances into the environment. For the regulated waste list as a whole, there remains considerable uncertainty concerning how and when this universe might increase or decrease without congressional action.

GOAL 3

Encourage alternatives to land disposal.

Only minor benefits in this area seem likely. There is little direct attention currently being given to promoting new management and technology approaches. The current RCRA program emphasizes using traditional command and control regulations for disposal of hazardous waste, with the belief that by making disposal options more stringently regulated and more costly, alternatives to disposal will become more attractive to waste generators. To some extent, this strategy and the "cradle to grave" system works. However, the success of the current approach relies on the imposition of, or expectation of, more stringent and more costly requirements for waste disposal facilities; the outcome is not yet certain.

An additional factor in the current program (which, some may argue, is more significant than the impact of the control regulations) is the effect of the liability requirements in RCRA and CERCLA. These requirements appear to be significantly impacting management decisions of both waste generators and facility operators. The primary effect is to shift priorities away from land disposal (with its uncertainties and potential liabilities for future release of hazardous substances) toward the use of economically attractive alternatives that more permanently deal with hazardous waste problems. However, there are uncertainties as to the impact of liability requirements because of:

1. the limited time that the liability requirements have been in place and the lack of information about compliance;
2. the varying, often limited policies offered by the insurance industry and the different and evolving procedures they use for evaluating risks;*
3. the perception by some that enforcement efforts are too ineffective to lead to determination of responsible parties;
4. the lack of experience with claims;
5. the very limited actuarial data concerning the risks associated with disposal technologies, with either existing facilities or new facilities, based on compliance with the final regulations;
6. changing and expanding legal theories of liability as a result of legislation and judicial decisions; and
7. the self-insurance provisions.

Moreover, there may be an indirect disincentive in current regulations. The performance standards for land disposal techniques are less detailed and, to some extent, less stringent and more flexible than the regulations for incineration. Therefore, the costs of incineration (determined, in part, by the regulations) remain noncompetitive with land disposal techniques. Furthermore, there are no final technical standards for some waste treatment technologies, such as certain chemical and biological treatments, which leads to much uncertainty about future regulation, and makes their commercial development and use difficult.

The current program generally does not regulate hazardous waste that is being recycled or put to "beneficial" use (e.g., waste burned as fuels), except for regulations covering transportation, storage, or generation. Therefore, the present policies can be regarded as providing an indirect incentive for recycling. Alternatively, this minimal level of regulation can be viewed as related to possible release of hazardous substances from such operations. Some justification for this concern exists because of the large number of CERCLA sites which have been selected for remedial attention that were recycling facilities originally.

Furthermore, current land disposal regulations do not distinguish where retrofitting of existing facilities may be both technically feasible and appropriate (see ch. 7). Nor do they consider how certain types of waste may be best managed in existing or new facilities depending on their hazard levels. The lack of restrictions on waste for disposal has two major effects. First, the long-term risks associated with land disposal may be increased, particularly for existing facilities. Second, the market for disposal techniques may be increased at the expense of treatment alternatives with higher direct costs. Also, there are no financial responsibility requirements for corrective action.

In summary, the current program indirectly promotes some use of alternatives to waste disposal. However, to the extent that the full short- and long-term costs of disposal options are still not fully internalized (because of the nature of the regulations and their effect on costs and markets, as discussed below), there remains an incentive to use disposal or dispersal options. Moreover, the current program does not directly provide counterbalancing incentives for alternatives to disposal, and EPA's R&D programs currently include very limited activities in the areas of advanced technologies and alternatives to disposal.*

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*There is no standard procedure used by insurance companies to assess the practices and risks of hazardous waste management facilities. Through a number of informal meetings between OTA staff and insurance industry personnel, it has been verified that risk assessment procedures vary substantially. Current procedures ranged from: no site inspection whatsoever; to relatively nontechnical inspections with no physical testing to verify past or present waste management practices, the nature of the waste managed, or the hydrogeologic nature of the site; to very sophisticated assessments involving highly trained personnel and physical testing.

GOAL 4

Improve data for risk assessment and RCRA/CERCLA implementation.

Because of the increasing maturity of the current program, with attempts to rectify acknowledged deficiencies in information and analysis, this option provides a moderate benefit. Problems remain, however. There appears to be an absence of a systematic, long-range program for expanding and maintaining a national hazardous waste data base. Coordination of efforts among different groups within EPA and other executive agencies appears insufficient. Responses to congressionally mandated efforts related to data and information have not been timely. Definition of the role of the States in data acquisition and analysis, and the provision of sufficient financial support for such State activities has not been accomplished. Partly as a result of these problems, there is a lack of information concerning unregulated waste that might be regulated in the future.

The limitations on data are related to what some consider to be a very disturbing aspect of current RCRA and CERCLA regulations—i.e., their lack of specificity concerning technical criteria. The regulations are, for the most part, based on performance rather than design, though often a mixture of both. There is concern, however, over the frequent lack of specific technical criteria to establish acceptable performance. Interpretations of many standards and permitting decisions are left to regional EPA administrators and permit writers. In some instances, they may be aided by advisories and technical resource documents issued by EPA. This approach can be defended on the basis that hazardous waste facilities and sites possess uniquely different characteristics. While flexibility is definitely needed, particularly from a State perspective, from a Federal perspective this approach may provide too little assurance that the intended stringency of the regulations will be obtained consistently throughout the Nation.

A particularly critical example of this lack of specific technical criteria is found in the National Contingency Plan under CERCLA where the "How clean is clean?" question is often posed. Although a reasonable process is specified for determining the extent of remedial cleanup, the absence of technical criteria places the CERCLA program in jeopardy. However, EPA believes this approach is appropriate because of the site-specific nature of the problem and the need to move ahead with the program expeditiously. Others believe that standards for allowable levels of release from sites after emergency or remedial action are needed. Such standards should be consistent with either existing Federal and State standards for levels of hazardous substances in the environment, or with available scientific information if regulations do not address the types of chemicals associated with hazardous waste. Much of the concern over this issue is related to the possibility of CERCLA-funded remedial actions that are found to be ineffective at a later date, when the State is responsible and CERCLA funds are no longer available.

Another important example of lack of specificity in RCRA regulations is the case of monitoring requirements. There are few technical criteria, based on hydrogeologic surveys and other information, for establishing the number and location of wells to determine water flows, background levels, and releases from the site. Similarly, there is little detail provided to establish a basis for EPA or State permit writers to decide which chemicals or indicator parameters are to be monitored, and which equipment and methods are to be used.

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*The phrase "from cradle to grave" used to describe the current RCRA program was created with land disposal in mind. However, it is interesting that in creating a metaphor for "from beginning to end" of "from birth to death" that grave was used to connote the end point of waste management. Considering both the extensive use of land disposal and the likelihood of releases of hazardous constituents into the environment, use of the word grave is somewhat misleading. A more apt and useful metaphor for the waste management cycle would be "from cradle to urn"—with urn suggesting incineration and true destruction of the waste as the most desirable end point.

Data collection and analysis for risk assessment is particularly important for determination of degree of hazard and subsequent regulation. There are two areas for which the determination of hazard or risk levels is being used or is being planned. One is for RCRA regulations, including the tailoring of regulations for some facilities, such as monofills (landfills for single wastes) and neutralization impoundments, specific wastes, provisions for class permits, and the setting of exemptions or prohibitions such as the small generator exemption. The other is in selection of uncontrolled sites for attention under CERCLA. EPA has faced a difficult task in applying hazard and risk assessments at a time when there is limited information, time, and resources, and when methodologies are still being developed. Nonetheless, there is considerable need to evaluate relative hazards and risks. The issue is not whether to attempt these evaluations, but rather which are the best technical approaches to use.

To satisfy Executive Order No. 12291, EPA is conducting regulatory impact analysis for RCRA regulations involving the use of the Risk/Cost Policy Model (sometimes referred to as the WET matrix). A detailed examination of this model is given in chapter 7 and its appendix. OTA is not confident that the structure of the model, its assumptions, or its data bases will lead to accurate results for estimating how regulations should be tailored, what waste should be exempt (such as under the small generator exemption category), or what waste should be prohibited from land disposal. Problems with the model are: the data base for waste now includes only about half of those regulated; the management technologies considered applicable are not consistent with present or possible future uses; diverse human health effects are not adequately addressed; costs for technologies are incomplete, undocumented, and are biased in favor of land disposal; and sensitivity analyses have not yet been performed.[11]

OTA is also concerned that the model is, in effect, an approach to cost-benefit analysis for RCRA—a balancing of the protection of human health and the environment against costs—which is contrary to congressional mandate. Moreover, in calculating benefits, the Risk/Cost Policy Model totally discounts any benefits from reducing risks associated with environmental damage. The model also makes use of population densities in a manner that could lead to determinations of low, and presumably acceptable, levels of risk for low population-density areas. Population near the site is an unreliable indicator of population at risk because of actual distributions of releases and varying exposures to people. Still, EPA has expressed confidence that the model can be used effectively as a complement to other information being gathered by the agency, including information obtained through its regulatory impact analysis program.

In the National Contingency Plan under CERCLA, a Hazard Ranking System (sometimes referred to as the Mitre model) is used to develop comparative rankings of hazard levels of uncontrolled sites in order to determine how limited resources can best be allocated. OTA's examination of this system has shown several deficiencies primarily concerning the type of data used, that can lead to false priorities and misallocation of resources. These are discussed in detail in chapter 7. The result is that CERCLA funds may be spent when large numbers of people may be at some risk, but that no funds are spent when relatively few people, such as in rural areas, are a high risk. Another problem with the model is the difficulty of incorporating data that may be more meaningful.

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[11] EPA's Science Advisory Board has reviewed this project. Its findings concerning the technical aspects of the model, for the most part, are in agreement with OTA's concerns, and it recommends continued development of the model. ("Report on the RCRA Risk/Cost Policy Model—Phase 2 Report," Environmental Engineering Committee, Science Advisory Board, October 1982.)

GOAL 5

Improve and expand RCRA/CERCLA participation by States.

There has been a marked increase in the level of both Federal and State activities and Federal and State cooperation is continuing. Nonetheless, the problems discussed previously indicate considerable room for improvement, and only a minor benefit with respect to this goal is likely. The current program is generally viewed by the States as presenting an unacceptable combination of shifting increasing responsibilities to the States without corresponding increases in necessary resources provided by the Federal Government. A potential exists for a sharp downturn in Federal-State relations if funding for State activities under RCRA subtitle C is eliminated, which EPA has indicated its desire to do and which it has already done for subtitle D activities. Lack of participation in policy formulation has also led to many States having substantial concerns over the effectiveness of the regulations promulgated thus far.

OTA has found the following problems to be significant and indicative of the current situation:*

1. States are viewed by EPA as critical to implementing regulations, but not in policy formulation and design of regulations. The result is that States often find themselves in strong disagreement with technical aspects of the regulations. For example, many States disagreed with EPA's small generator exemption based on quantity rather than on hazard level and with EPA's policies on liquids in landfills. Also, many States find land disposal regulations too weak in the monitoring area, particularly the exemption from the ground water monitoring and response requirements. Although States may, and sometimes do, impose more stringent requirements than the Federal program, the absence of strong Federal action may undercut State efforts, and limited State resources restrict the development of separate and more stringent State regulations. In the case of CERCLA, States have expressed considerable concern over the lack of detail in the National Contingency Plan.
2. States have continuing problems because of the decision to remove all Federal grant support for subtitle D nonhazardous solid waste activities, even though these programs are far from complete. Moreover, such facilities are allowed to accept hazardous waste under the small quantity generator exemption. There is considerable concern that some sanitary landfills may, therefore, become future CERCLA sites. However, there are often no funds available to monitor these sites for release of hazardous substances. Some RCRA subtitle C grant funds are being used for subtitle D activities, and EPA does not appear to be carrying out its responsibility under RCRA subtitle D to oversee the State solid waste programs.
3. States have no ongoing Federal grant support for general CERCLA activities related to identifying and assessing sites. CERCLA funds now received are only for specific emergency or for remedial site actions. Some RCRA subtitle C funds are being used for CERCLA activities.
4. States have not received increased Federal grant support, while RCRA activities have escalated sharply. Furthermore, because of the two preceding factors and insufficient State funds, RCRA subtitle C grants are used to carry out other activities. In fact, EPA has indicated its intention to eliminate all grants to the States;* and in

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*For detailed comments on Federal-State problems from the State's perspective, see, various testimonies by Norman H. Nosenchuck, as President of the Association of State and Territorial Solid Waste Management Officials and Director of the Solid Waste Management Program for New York State; and various congressional hearings, such as Senate Subcommittee on Intergovernmental Relations, Nov. 24, 1981, and House Subcommittee on Natural Resources, Agricultural Research and the Environment, Dec. 6, 1982. Also see, Jacqueline M. Rams, "Federalism and Hazardous Wastes—A Perversion of RCRA Intent?" *The Environmental Forum,* January 1983, pp. 11-16.

*In a meeting between the EPA Administrator and representatives of the National Governors' Association on Sept. 20, 1982, the States indicated that reductions in grants would lead to cutbacks in programs. This would impede delegation to some States, and cause formation of "pollution havens." They also indicated the fiscal year 1983 authorization process, EPA wanted to reduce State grants, but Congress restored the level of funding.** This is in sharp contrast to an EPA statement in 1980:

> To carry out their responsibilities under subtitle C, the States will have to expand greatly the size of their hazardous waste programs. Program expansion might require a corresponding increase in State hazardous waste management grants.[12]

The 1980 EPA projection for the State grants for fiscal year 1983 (in 1983 dollars) is nearly three times greater than the amount actually budgeted for fiscal year 1983.

5. States have had few direct, formal, and consistent ways to influence, to support, or to contest the data at EPA. They often are expected to use unreliable and incomplete information, or to supply information without having the resources to obtain it.
6. States find themselves in conflict with EPA over the choice of sites for CERCLA funding because of the requirement to provide at least 50 percent of the initial costs for State or local government-owned sites and 10 percent for private sites. Because of limited State funds, government-owned sites may be less likely to be chosen by States for CERCLA attention on the grounds that more sites could get remedial attention by using the available funds as the 10 percent match for CERCLA actions at privately owned sites. There are also indications that a bias exists in favor of selecting sites associated with those industries whose feedstocks are now taxed under CERCLA. Moreover, the choice of remedial technologies for CERCLA sites creates further conflicts because of the State's responsibility to cover all future operating and maintenance costs. States are concerned that EPA will favor approaches with low initial costs, but high continuing costs. EPA has indicated that it will select the lowest cost-effective alternative, and States preferring a higher cost alternative must pay all additional costs.
7. The general character of the program to delegate responsibility to the States favors programs identical to the Federal program. States are reluctant to develop deviations that would jeopardize "equivalency" with the Federal program, but which might be well suited to local conditions and needs.

GOAL 6

Moderate increases in costs to governments for administration and to industry for compliance.

The status quo may appear to provide benefits in these areas. However, there is some concern that the current program, not merely in the content of its regulations, but also in its administration, places considerable emphasis on balancing short-term, immediate costs against protection of public health. It has largely discounted efforts to protect against longer term environmental effects. The structure that provides flexibility for site-specific factors could also lead to excessive responsiveness to local economic interests desiring to minimize management costs. Furthermore, there are no programs aimed at shifting management choices to alternatives that are more costly than land disposal in the short term. There is no means of proving that the current program is or is not, ultimately, a cost-effective approach. Some of the measures being contemplated for "fine tuning" of the program (e.g., tailoring land disposal regulations according to perceived risks and costs) may lead to greater cost effectiveness, but it is not possible to forecast that adjustment of overregulated cases will more than offset ad-

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State fee systems cannot compensate, and that grants are not a gift, but represent a purchase of services, and that without grants States ought to begin charging for services and data provided. NGA memo from Tom Curtis to Environmental Directors, Sept. 23, 1982.

**When the administration proposed a 20 percent reduction in fiscal year 1983 grants to the States, a study revealed that Federal grants to the States support 69 percent of State hazardous waste program budgets, that 11 States hoped to replace at least part of the reduction in grants, and that 20 States would reduce monitoring proportionately to the grant reduction. "The State of the States: Management of Environmental Programs in the 1980's," National Governor's Association, June 1982.

[12] "Operations/Resource Impact Analysis, RCRA Subtitle C" (Washington, D.C.: Environmental Protection Agency, April 1980).

justment of underregulated cases in terms of costs alone.*

GOAL 7

Reduce risks transferred to the future; reduce costs of management shifted to society in general.

It is clear that the current program offers significant reductions in the transfer of risks and costs to future generations than before its implementation. Nonetheless, this option is believed to offer only a minor benefit relative to what is achievable and socially desirable. The current program is generally perceived to broadly sanction land disposal, and there are uncertainties over possible future costs. Uncertainties concerning the choice and effectiveness of remedial actions under CERCLA are also substantial.

EPA has used the qualifier "long term" in its land disposal regulations, but has not made the meaning of this term exact. It is reasonable to interpret the phrase to mean about 30 years, a number in keeping with other language in the RCRA land disposal regulations. There then appear to be ample opportunities for facility operators to adhere in good faith to the regulations and create situations that transfer risks and financial liability to future generations. Not all releases may be detected within 30 years. As noted in final land disposal regulations, EPA itself expects, " . . . most landfill disposal units to leak [eventually], however well designed . . ." The time horizon problem is particularly apparent in the monitoring requirements for land disposal techniques and the ways in which monitoring requirements can be circumvented entirely.

GOAL 8

Reduce public concerns over siting of facilities.

Only a minor benefit is likely. Public confidence does not appear to be improving with the current program. There are no Federal programs that would indicate to the public that alternatives to land disposal are being encouraged. Nor are there strong signals that technical information is being both improved and better disseminated in useful forms to the public. There are no indications of interest in providing direct Federal involvement in the siting area which might complement State efforts. Many States have instituted programs and criteria for siting to alleviate public concerns, but the results are not yet clear. Alternatively, continuing information, analyses, and discussions of the current national regulatory program contribute to public concerns.[13]

Option II
A More Comprehensive and Nationally Consistent RCRA Program

The purpose of this option is to expand the scope and increase the effectiveness of the current RCRA program. The changes discussed below could be carried out by amendment to RCRA, possibly including a schedule for EPA implementation within approximately 6 months to 1 year of enactment. For convenience, all changes in RCRA are presented as one congressional option, although each could be enacted independently. Each of the modifications is described, followed by an evaluation of the option in terms of the eight policy goals presented earlier; then, the costs and problems associated with implementation of the option are discussed.

Specific Changes

Wastes Regulated.—This change concerns the universe of regulated hazardous waste and the extent of such regulation. The findings of this assessment support consideration of the following measures to bring more high-priority waste under regulation in appropriate ways:

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*An important but uncertain factor, for this and all policy options, is general economic conditions, including levels of industrial capacity utilization, types of industry restructuring, shifts in end-product uses, and the development of new industries and processes. Some of these can lead to lower costs for waste management, while others may increase costs. Nonetheless, it is likely that the costs for hazardous waste management (as either a fraction of gross national product or of a waste generator's production costs) are likely to increase in the near term, stabilize, and possibly decrease as waste prevention and control techniques become more pervasive, mature, and efficient, and with reductions in the formation and remediation of uncontrolled sites.

[13] For example: "State of the Environment 1982," The Conservation Foundation, 1982; "Indictment—The Case Against the Reagan Environmental Record," ten environmental organizations, March 1982; "Environment and Health," *Congressional Quarterly*, 1981; and "Poisons in the Water," Sierra Club, October 1982.

1. Closing the gap created by the blanket exemption of hazardous waste generated in relatively small quantities. The objective is to avoid having hazardous waste managed as nonhazardous, solid waste in sanitary landfills. In the near term, if a quantity cutoff is used, the prudent approach would be to use a relatively low one such as 100 kilograms per month (kg/mo) instead of the current 1,000-kg/mo value. In the longer term, however, some measure of the level of hazard of the waste could be used instead. Such an approach does not imply adoption of any particular, or complex, methodology for assessing level of hazard. Regulation would be based on known characteristics of the waste that indicate potential harm to human health and the environment upon release of the material into the environment and with significant exposure. However, if it could be demonstrated that relatively small quantities of hazardous waste do not present significant threats, then there could be very minimal regulatory control, e.g., notification and reporting requirements, or modification of RCRA regulations that govern waste generators.[14]
2. Ending the total exemption for hazardous waste used as fuels, or as fuel supplements. Instead, there would be notification requirements for records of what wastes are being burned and where. Also, there would be standards for acceptable levels of release into the environment, and perhaps some monitoring requirements.[15]
3. Ending the total exemption from RCRA coverage of liquid hazardous waste sent to municipal water and sewage treatment facilities. There would be instead notification requirements and standards for acceptable amounts of releases and residuals in effluent waters and sludges, supplementing gaps in pretreatment coverage under CWA. These requirements and standards would be defined for specific chemicals and toxic metals in a manner consistent with types and concentrations of constituents.
4. Establishing a category of "special" hazardous waste consisting of high-volume, relatively low-hazard waste (many of which are now totally exempted from regulation) to be minimally regulated under RCRA. There may be only notification requirements for generators of such waste.
5. Developing minimal regulations for the recycling of hazardous waste (or hazardous materials that could become waste), applicable to all operations, not just "third party" recyclers as is currently proposed. Due consideration would be given to avoiding the creation of disincentives for recycling—e.g., by only requiring notification of what wastes are being recycled.
6. Developing lists of hazardous wastes to be prohibited from management in landfills, surface impoundments, and deep wells. These lists should be correlated with technical criteria regarding particularly high

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[14] A detailed OTA study of the small generator exemption found that waste produced at a rate below 1,000 kg/mo could amount to 2.7 million to 4 million tonnes annually nationwide. Amounts vary substantially among States—16 States indicated that more than 5 percent of their waste came from small generators. (OTA, "The RCRA Exemption for Small Volume Hazardous Waste Generators," staff memo, July 1982.) A more recent study for New England States indicates that over 15 percent (excluding waste oils) of the region's waste is produced by small generators. (A. D. Little, Inc., "Hazardous Waste Generation in New England," August 1982.)

[15] Current EPA policies on the burning of hazardous waste as fuel are generally not related to the hazards posed by suboptimal burning that may lead to release of hazardous constituents into the environment. For example, some wastes are totally exempt from regulation if they are to be recycled; these are "wastes that are not sludges, that exhibit a characteristic of hazardous waste, and that are not listed in 40 CFR 261.31 or 261.32." Moreover, the determination of whether the recycling is "legitimate or sham" depends primarily on the energy value of the waste, rather than any consideration of the performance characteristics of the burning operation, the hazardous nature of the waste, or risk factors associated with releases and exposures. (EPA, *Memorandum on RCRA Enforcement Guidance: Burning Low Energy Hazardous Wastes Ostensibly for Energy Recovery Purposes*, Jan. 18, 1983.)

risks from possible releases into the environment.

7. Establishing regulatory criteria for hazardous waste which, although substantial scientific information indicates their hazardous character, have not yet been so defined. They have not been listed and, when subjected to current EPA tests and procedures, they do not exhibit any of the currently identified hazardous waste characteristics. For example, a number of industrial wastes containing significant levels of dioxins, chlorinated organics, or pesticides are not now regulated as hazardous wastes and cannot be shown to be toxic by EPA's test for toxicity.

   EPA's extraction procedure (EP) test for toxicity has received considerable discussion and criticism. Its use for defining RCRA regulated waste and for delisting decisions is highly suspect. A recent technical study of the EP test by Utah's hazardous waste management program concluded:

   > The EP test procedures as presently adapted definitely need to be refined and changed. The results from this test are not adequate to make sound waste management decisions. In fact, the EP results obtained are leading to mismanagement decisions with accompanying risks of adverse health or environmental results.[16]

   The study showed how waste with oily phases presented particular problems, that organic waste posed problems, that results are not reproducible, that the acetic acid extraction medium does not model real world conditions, that the test's 20-fold dilution for solid samples produces deceivingly low results, and that false negative results were likely. Some sites in Utah where wastes that are not hazardous, according to the EP test, have been land-disposed and have already contaminated ground water.

   Another example of the limitations of the EP test has been shown for cadmium-containing sludge produced in Illinois. In order to pass the EP test, calcium oxide is added to the sludge. The lime does not alter the cadmium, but it does neutralize the acetic acid used in the test and allows the sludge to be classified as a nonhazardous waste.[17]

8. Making delisting of hazardous waste more expeditious without, however, compromising protection of the public. This could be done by using clearer, specific criteria for delisting and by limiting times for evaluation by EPA. To some extent, this action could balance the effects of the preceding actions, which lead to more waste being regulated. Delisting provides a means whereby site-specific factors or previously unavailable information might mitigate prior estimates of potential hazard. However, one problem that has become apparent in delisting processes should be controlled. Although constituents causing a waste to be originally defined as hazardous may have been removed, the waste may still contain other hazardous constituents in significant concentrations. Such waste should not be delisted, pending further testing. The use of the EP toxicity test (as discussed above) should be examined. Adopting a procedure for verification of submitted data should also be examined. Attention is also needed to address current delisting activities which may be delaying the regulation of significantly hazardous waste, such as dioxin.[18]

Limited Class Permits.—The engineering design and performance characteristics of some hazardous waste management facilities may be largely independent of location. Class permits may be appropriate for such facilities. However, such facilities should have little probability of release of hazardous constituents, and such possible release should be easily observable through minimal, mandatory inspection or monitoring. There is some concern over whether permitting by rule would lead to sufficient protection of the public, such that the loss of public participation in the permitting process is justified. Furthermore, while use of class permits for tanks and containers may be reasonable, these may have to be limited to aboveground facilities because of the difficulty of detecting leaks in underground facilities. Limited class permits may have to be based on very detailed technical criteria in order to avoid permitting of older facilities having unacceptable design and performance features. (For example, construction materials in older facilities may lack adequate corrosion resistance.) If Congress is to sanction class permitting without sacrificing protection of the public, then the limited nature of the policy should be carefully spelled out legislatively. Class permitting need not involve a cutoff of all public participation. Expedited, minimal permit review can be combined with appropriate notification and an opportunity for the public to be heard as part of the permitting process.

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[16] "Comments of the Utah Bureau of Solid and Hazardous Waste on the Extraction Procedure Toxicity Test," Dec. 1, 1982.

[17] W. C. Geissmen, letter to Rep. James J. Florio, May 25, 1982.

[18] House Energy and Commerce Committee Report No. 97-570 on H.R. 6307, May 18, 1982, p. 23.

Specific Technical Criteria in Regulations.—There are a number of critical components of RCRA and CERCLA regulations that include little if any specific technical criteria to guide permitting. If Congress is to ensure protection of the public consistently, then it is necessary to direct EPA to establish specific technical criteria through rulemaking, in contrast to reliance on guidance documents. This would correct the current emphasis on allowing Federal or State permit writers to make critical decisions either without such guidance, or without the resources necessary for making decisions and formulating criteria about extremely complex technical matters. Two areas of particular concern are RCRA regulations dealing with monitoring for land disposal facilities and CERCLA regulations dealing with the determination of the extent of cleanup at a remedial site. This is not to imply that EPA is unaware of the problem. Several relevant activities should be noted: draft guidance documents have been prepared by EPA and may lead to specific criteria being used; EPA was under judicial order to promulgate final regulations; and regulations can and may be revised in the future to add more detailed standards.

Benefits of the Option

The above set of changes in the current Federal regulatory program for hazardous waste would yield the following benefits relative to the eight goals for all policy options. That the option could readily be implemented is an intrinsic advantage.

GOAL 1

Improve protection of health and the environment without undue delays and uncertainties.

In general, this option appears to offer a major benefit. Regulation of more hazardous waste, use of more technical criteria in regulations, and reasonable class permits could reduce the probability of release of hazardous constituents into the environment. The option would not restructure the current Federal program. All the modifications in RCRA could be implemented expeditiously within the existing framework in an evolutionary manner. The option presents changes which can be phased in and which would reduce uncertainties concerning possible future regulation. One specific action that would benefit from the earliest possible consideration is the adoption of specific technical criteria for permitting, which has hardly begun. Such criteria could speed up permitting in many respects; current regulations are likely to place considerable burdens on permit writers.

GOAL 2

Expand universe of federally regulated hazardous waste.

This option offers a major benefit. Many existing gaps in regulatory coverage would be closed in appropriate ways. Addressing the delisting mechanism from the viewpoint of waste generators (ensuring that truly hazardous waste are not delisted) balances increased burdens placed on waste generators by accommodating unique site-specific situations.

GOAL 3

Encourage alternatives to land disposal.

Only modest, indirect benefits are likely in this area. Bringing more waste under regulation may create larger markets for alternatives. The use of more specific technical criteria might make land disposal options more stringent and costly.

GOAL 4

Improve data for risk assessments and RCRA/CERCLA implementation.

The option would promote the use of more specific technical criteria in regulations, as well as for the collection of additional information concerning additional waste brought into the regulatory system (even if only for reporting). There are, thus, reasons for expectation of major benefits regarding data collection, risk assessment, and implementation.

GOAL 5

Improve and expand RCRA/CERCLA participation by States.

A major benefit could result because more technical guidance would be provided through the use of more extensive technical criteria in Federal regulations. Also, States that now regulate more waste than the Federal system would have fewer conflicts with the expanded Federal system, and would find program delegation more acceptable. This option would facilitate expansion of the universe of regulated waste for those States that cannot be more stringent than the Federal program. Many States would also welcome class permits and more technical criteria in regulations, which could reduce the burdens on State permit writers. However, this option would not expand participation by States.

GOAL 6

Moderate increases in costs to governments for administration and to industry for compliance.

Only a minor benefit might result. By bringing more waste into the regulatory system, this option increases all costs. To the extent that class permits and more equitable delisting procedures might offer efficiencies, costs might be reduced. If it is presumed that greater regulatory coverage reduces long-term costs to the government for cleanup actions, then the option may offer a long-term cost benefit.

GOAL 7

Reduce risks transferred to the future; reduce costs of management shifted to society in general.

A major benefit in this area would result from the fact that more hazardous waste would become regulated and managed in more appropriate ways than they currently are. More technical criteria in Federal regulations could also ensure that current managers provide appropriate levels of control.

GOAL 8

Reduce public concerns over siting of facilities.

A major benefit could result with public perception that the Federal regulatory system ensures that fewer hazardous waste are escaping regulation altogether and that increased technical criteria in Federal regulations provide a more uniform and acceptable level of protection throughout the Nation, without removing the public's right to participate in the permitting process.

Costs and Problems for Implementation

Some of the specific actions required for implementation are consistent with current EPA plans, although details may differ.* Other actions, such as broadening of the regulated waste coverage and use of specific technical criteria, are not wholly endorsed by EPA. A major problem appears to be the somewhat increased resources required to implement the changes. Critics may contend that with practical implementation just beginning, it is not possible to keep the current program moving, while at the same time making these changes. It may also be argued that there is insufficient information available to carry out these changes. Opponents of the option are likely to see an unnecessary increase in the scope and level of the regulations, adding further to the burden on the regulated community. There is some merit to all these viewpoints. There is no way to determine precisely what the costs to government, or to the private sector, would be. A rough estimate of the increase in EPA funding required for implementing this option within 1 to 2 years might be about $10 million.*

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*For example, EPA has indicated that it is studying the burning of hazardous waste as fuels in boilers and may issue regulations, but its study will not be completed until early 1984, and it has begun a study of small generators. EPA plans to propose rulemaking for the first group of class permits in 1983. (47 CFR 239, 5580-5584, Dec. 13, 1982.)

Option III
Use of Economic Incentives for Alternatives to Disposal and Dispersal

The objective of this option is to shift the balance from disposal and dispersal of hazardous waste into the land or the oceans to the reduction of waste at the source, recycling, and treatment. Direct economic incentives would be used to accomplish this objective. The following comments from a recent study[19] suggest a need for this option:

> The federal government has done little directly to encourage the adoption of alternative disposal techniques . . . Several of the states are taking a more active role than the federal government.

This option is designed to provide **direct** incentives. There are, within the current program, regulatory incentives to promote the use of alternatives to disposal and dispersal, including: streamlining permitting procedures for alternative or innovative facilities, requirements to use certain alternatives for specific wastes, and increasing the required level of control for disposal and dispersal approaches. Moreover, the current system is significantly increasing the costs of land disposal, compared even to just a few years ago. While these factors may have beneficial effects, they are often rendered less effective by uncertainties, ambiguities, and contradictions in the regulatory system (as perceived by the regulated community) or because they limit choices in too general a fashion. The use of direct economic incentives can be viewed as a complement to regulatory incentives and to the use of the legal system.

This policy option should be viewed in the context of current legislation concerning hazardous waste management. CERCLA was enacted because of the recognition that unacceptable risks have been inherited from certain past waste management efforts that were too shortsighted. **The connection between CERCLA and RCRA has received insufficient attention; too often they are viewed as separate programs, rather than as two components of the Federal hazardous waste program.** The need for future expenditures of public funds to clean up hazardous waste sites should be minimized.

Congressional action to implement this option could occur through an amendment to RCRA or CERCLA, or as new legislation. There are no apparent technical or institutional obstacles to adoption, but a major issue would be what types of incentives to provide. Consequently, before discussing here the several types of economic incentives, the concept of a **hierarchy of alternative management strategies** is examined. The discussion provides a context for considering this option. Second, a comprehensive set of economic incentives are examined, including using a fee system for wastes, a means to address capital needs, and a means to address R&D needs. Third, the option is evaluated on the basis of the eight policy goals. Finally, costs and problems associated with implementation are discussed.

A Hierarchy of Alternative Management Strategies

A major purpose of chapter 5 is to demonstrate the applicability of a relatively large number of alternative technological approaches to hazardous waste management. Such technologies provide means for the reduction of waste generation, the destruction of waste, and the disposal or dispersal of waste. **Different alternatives are appropriate for different wastes and locations.** In chapter 4, it was noted that land disposal nationwide continues to be used for most hazardous waste (although it varies substantially among States), and in chapter 5 the uncertainties concerning the use of ocean disposal are discussed.

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*This figure is roughly 40 percent of the sum in the EPA fiscal year 1983 budget for all hazardous waste activities excluding grants to the States, administration of the regional offices, enforcement activities, and R&D activities; it is also about one-third of the fiscal year 1983 budget for R&D costs associated with hazardous waste.

[19] "State of the Environment 1982," The Conservation Foundation, 1982.

With the congressional mandate to reduce the risks associated with hazardous waste to acceptable levels for both present and future generations as a constant goal, a cost-effectiveness approach can be used to select appropriate technical approaches for particular wastes. Moreover, the optimum management strategy for any waste will likely consist of several technical steps: reducing the volume of waste, reducing the hazard level through treatment, and disposing or dispersing what remains. It must be recognized, however, that occasionally some treatments might lead to waste residues that present greater problems for disposal than the original waste. The most attractive management strategy is one that matches technological operations with the characteristics of specific wastes to minimize the release of hazardous waste in a cost-effective manner. Greater attention to a hierarchy could lead to greater consideration of the broadest range of cost-effective alternatives for waste management. Available management strategies and specific technological alternatives appear to provide ample choices for waste generators to obtain solutions to regulatory demands.

The following hierarchy provides a framework for understanding the use of alternatives to disposal and dispersal of hazardous wastes:

1. **waste reduction** at the source—e.g., process modifications;
2. **waste separation, segregation, and concentration,** through available engineering techniques in order to facilitate identification of the waste and the application of the remaining steps;
3. **material recovery,** either onsite or offsite, to make use of valuable materials, including the use of waste exchanges so that a (potential) waste for one generator can be made available as a resource for another industry;
4. **energy recovery** from (potential) waste or its components, perhaps as a fuel supplement;
5. **waste treatment** to reduce the hazard level and possibly the amount of waste requiring disposal; and
6. **ultimate disposal or dispersal** (preferably of residues from previous steps, of pretreated waste, and of untreatable waste) in a manner that holds release of hazardous constituents into the environment to acceptable levels.

Such a systematic ordering of waste management options presents a number of advantages. For example, permanent solutions to waste problems are more likely to occur prior to disposal and dispersal. Consequently, fewer risks and costs are shifted to the future. Emphasis on waste reduction could significantly reduce costs of waste management and, in some instances, avoid them altogether. The use of waste as resources, rather than discarding them, at once removes them and provides direct economic benefits. If less hazardous waste is produced and regulated by promoting the use of alternatives 1 through 5 of the hierarchy, and if there are reduced administrative activities (e.g., inspection) for treatment and disposal facilities, then the costs of administering a regulatory program and of remediating uncontrolled sites could be reduced.

Specific factors concerning waste, plant, and companies should of course play their normal role in economic evaluations of alternatives. Moreover, for some waste only management alternatives 5 or 6 will be technically feasible or cost effective. The above listing does not imply that alternatives 2 through 5 do not involve any potential release of waste into the environment; techniques for these options require some regulatory coverage to monitor and hold such release to an acceptable level. For example, energy recovery through the burning of waste as fuels poses problems of releases of hazardous constituents into the environment.

Such regulation can provide information useful in enforcement efforts and for understanding how generic types of waste can be managed other than by disposal and dispersal approaches.

The idea of the hierarchy presented above did not originate with OTA. It has been recognized for some time by those concerned with waste management in both industry and government. In 1976, before the passage of RCRA, EPA offered a position statement on effective hazardous waste management that included the above hierarchy as a ranking of **preferred** alternatives. As recently as 1982, EPA reiterated its support of the 1976 position.[20] Nonetheless, there has been little programmatic support of the concept of a waste management hierarchy. Although RCRA gave some attention to reuse, recovery, and recycling, there have been few programs providing incentives, nor have there been transfers of technology and information encouraging this strategy. As for EPA's R&D activities, in fiscal year 1983 the total effort related to alternatives to land disposal amounted to about 10 percent of all hazardous waste R&D, or $4.4 million.[21] (See ch. 7 for a discussion of all current EPA expenditures.)

There have been no programs explicitly aimed at waste reduction, although increasing costs of waste management (due, in part, to the Federal regulatory program) have indirectly encouraged waste reduction efforts. **The indirect approach, however, does not appear to produce positive results extensive enough and fast enough to substantially impact national waste management practices.** Some support for this belief has been obtained by an analysis of premanufacturing notices filed by manufacturers of chemicals as required by the Toxic Substances Control Act. Limited information provided on anticipated waste management practices for notices filed during the past 3 years, as shown in table 10, indicate two trends: 1) increasing reliance on some form of waste treatment by itself, and 2) a decline in the use of land disposal by itself and in conjunction with waste treatment. However, the total, combined use of land disposal continues to remain at high levels, and the increase in notices filed may indicate increasing amounts of waste to be produced in the future.

The ineffectiveness of indirect incentives probably will likely remain as long as EPA maintains that land disposal is the most acceptable management alternative. Thus, although EPA has adopted the above hierarchy, its position regarding land disposal has been expressed as follows:

> We believe that most wastes can be satisfactorily managed in the land and that it can be done with a reasonable margin of safety more cheaply in this manner.[22]

Indirect, nonregulatory approaches to this option are of only limited effectiveness. Adequate control of hazardous waste cannot be provided by either market or legal systems, as was concluded in a recent study for EPA:

> Private markets alone cannot be relied on to promote adequate controls on hazardous releases. The common law system creates some

Table 10.—Waste Management Methods Indicated on TSCA Premanufacturing Notices

Year	Treatment only	Treatment and land disposal	Land disposal only
1980......	24%	41%	30%
1981......	29%	29%	41%
1982......	52%	31%	13%

NOTE: Based on examination of May and June submissions for each year. Percentages are for totals of those supplying information for onsite and offsite management; totals were 37 for 1980, 68 for 1981, and 118 for 1982. Due to the limited information asked for and provided, it is not possible to know whether all the management choices are for hazardous waste, or for others as well.

SOURCE: Office of Technology Assessment.

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[20] Federal Register, vol. 41, No. 161, pp. 35050, 35051, 1976; *EPA Journal*, July-August 1982, p. 19; and testimony of Rita M. Lavelle, U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Natural Resources, Agriculture Research and Technology, Dec. 16, 1982.

[21] The actual areas and support levels are: incineration of organics—$2.6 million, cofiring options such as boilers and cement kilns—$1.2 million, advanced thermal technologies such as plasma burning—$140,000, physical, chemical, and biological treatments—$150,000; pretreatments such as solidification—$300,000. (Oral testimony, John Lehman, Director of EPA's Hazardous and Industrial Waste Division, House Subcommittee on Natural Resources, Agriculture Research and Environment, Dec. 16, 1982.)

[22] Testimony of Rita Lavelle, House Subcommittee on Natural Resources, Agriculture Research and Environment, Dec. 16, 1982.

> incentives for proper waste management, but those incentives are too weak or uncertain to provide the only controls for many types of hazardous waste incidents.[23]

The study did not address the question of whether equitable internalization of the full costs of hazardous waste management can be achieved through a regulatory approach, nor did it consider nonregulatory alternatives which might avoid inadequacies of the market and legal systems. Such questions are becoming increasingly important.

With regard to the use of direct economic incentives, a 1980 EPA study noted:

> Many environmental regulatory programs could potentially employ market mechanisms to supplement or replace the more traditional "command-and-control" approach. There is good reason to believe that in some cases market incentives might be both less costly and more effective than the regulatory approach.*

Many industries have actually adopted the above hierarchy. Their economic evaluations include the longer term liabilities and potential costs associated with the disposal and dispersal alternatives, which are more difficult to quantify than short-term costs. Industries choosing to reduce waste generation or to use treatment techniques may incur greater costs than competitors who choose disposal and dispersal. Adoption of the above hierarchy, even in the private sector, must be based primarily on a philosophical commitment, not on precise quantitative economic evaluations of limited scope. Some industries may want to convey to the public that their firms are "good citizens." Although use of the land for disposal has continued to receive regulatory attention, many would argue that land disposal has been encouraged (see ch. 7) by regulations that fail to promote internalization of the long-term costs of land disposal. Since current regulations contribute to the lower costs of disposal and dispersal when compared with other alternatives, it can be argued that measures need to be taken to offset this regulatory bias. One approach would be to correct the regulatory bias directly. Another would be to address the need for direct economic incentives for alternatives to disposal and dispersal. The incentive approach contrasts with the traditional command and control regulations which are aimed at uncovering those not in compliance and depend on enforcement actions.

Types of Incentives

Considering the objective of minimizing government expenditures, OTA believes that it is impractical to suggest major incentive programs based on direct, budgeted expenditures. Also, the use of economic incentives raises questions concerning the placement of burdens on industry. For such reasons, this option consists of three components: a fee system on generated waste, procedures to respond to capital needs of alternatives, and consideration of R&D problems that might prevent the development of alternatives.

A Fee System.—There is a trend toward State use of fee systems, both to raise revenues and to influence choices among hazardous waste management alternatives, but results of these relatively new programs are mixed. California, New York, Kentucky, Missouri, and Ohio impose fees on waste generators. The CERCLA program, at the Federal level, is based on the collection of a fee on the production of petroleum feedstocks and specified chemicals which produces 87.5 percent of the $1.6 billion fund. Many critics of this approach believe that the fund should have been financed through a "tail-end" fee on actual waste generated, rather than on "front-end" feedstock materials that only indirectly, and to different degrees, lead to hazardous waste generation. A strong disincentive is thus inadvertently established penalizing those choosing to minimize waste generation. However, there was insufficient information on waste generators originally available to facilitate such an approach. When collection under CERCLA expires in 1985, it is likely that substantial sums will continue to be required to clean up uncontrolled sites. EPA's original estimate in 1980 required $44 billion. There have also been indications from the administration that it is currently disinclined to seek reauthorization of the fee collection program. **Continuation of the current CERCLA fee system offers no direct incentive to alternatives to land disposal, although continued experience with CERCLA may prove to be an effective indirect influence on use of such alternatives.**

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[23] "Evaluation of Market and Legal Mechanisms for Promoting Control of Hazardous Wastes" (draft), Industrial Economics, Inc., September 1982.

*EPA, "Economics In EPA," Subcommittee on Economic Analysis, Science Advisory Board, July 22, 1980.

An approach that would satisfy several objectives could be based on the use of the CERCLA funding mechanism for RCRA purposes and using a tail-end system instead of a front-end fee. This would involve shifting the collection of CERCLA moneys (including the post-closure liability trust fund to start in 1983) to hazardous waste generators.* To be effective, fees would have to be reduced, on a unit-weight basis, when: 1) alternatives to disposal and dispersal were used by the generator, either onsite or offsite; and 2) the hazard level of the waste or residue disposed was relatively low.

The concept of a fee on waste generators has been given some support by the recommendation that the Hazardous Waste Compensation Fund "should be established by contributions from, or taxes on, the production of hazardous or toxic chemicals, and crude oil, and by a tax on the deposit of hazardous wastes."[24] Moreover, EPA itself has said that ". . . fee systems make sense because they 'internalize' the cost of pollution, placing its cost at the source, not on the general public,"[25] although EPA seems more interested in State fee systems than in a Federal system. With regard to the present approach to collecting fees on feedstocks under CERCLA and the need to influence current management choices, the senior EPA official responsible for both CERCLA and RCRA administration has said, "It would be more appropriate to put the fee on waste generation."[26]

Support for a waste fee system also has come from a major industry, which is generally understood to be the largest hazardous waste generating industrial sector:

> CMA has, under the Superfund discussions, recommended a waste end tax. That may be one way to increase the incentives out of landfilling for certain particularly highly toxic materials. Waste end tax as opposed to a feedstock, and I think that probably should still be considered as one of the methods which might be used to move the system gradually from landfilling to the more appropriate, in some cases, technologies.[27]

In considering the problem of Federal funding of State programs, the National Governors' Association has said,

> If EPA wishes fees to replace federal resources, it should lead the way with the development of a uniform fee structure, ...[28]

The critical feature of such a system, is that such a fee should be substantially greater (perhaps double) for disposal and dispersal options, and substantially lower for low-hazard or treated waste (perhaps by half). A fee discrimination would provide the desired economic incentives for alternatives to disposal and dispersal. Moreover, the discriminatory ratios and/or the amounts of the fees on land-disposed wastes might be increased over time, as waste volumes decline and after ample time has been given for adopting alternatives. A zero tax for wastes (or portions of them) recycled for material or energy that would otherwise become hazardous waste would appear equitable and desirable.* However, there is a need for precise definitions for recycling (as well as for hazardous waste), otherwise a waste fee approach could lead to inappropriate removal of wastes from the system.**

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*Collection of the $2.13 per ton CERCLA tax on hazardous waste received at treatment, storage, and disposal facilities will begin on Apr. 1, 1983. No tax is paid on waste that will not remain at the facility after closure, such as treatment facilities. The tax is not on waste generators directly. Proceeds of the tax will finance the $200 million Post-Closure Liability Trust Fund to pay for post-closure care, remedial action, and damages from releases at qualifying hazardous waste facilities.

[24] "Injuries and Damages From Hazardous Wastes—Analysis and Improvement of Legal Remedies," report to Congress by Superfund Study Group, September 1982.

[25] Issue papers prepared by EPA for Sept. 20, 1982, meeting between EPA Administrator and representatives of the National Governors' Association, distributed by Lewis S. W. Crampton.

[26] Oral testimony, Rita Lavelle, U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Natural Resources, Agriculture Research and Environment, Dec. 16, 1982.

[27] Philip A. Palmer, testimony on behalf of the Chemical Manufacturers Association, Mar. 31, 1982, House Subcommittee on Commerce, Transportation, and Tourism.

[28] "Work Plan on Environmental Program Grants," Environmental Subcommittee, National Governors' Association, Dec. 16, 1982.

Can fees on generated hazardous waste raise sufficient revenues? If one accepts the current, frequently used figure of 41 million tons per year of RCRA hazardous waste generation, an **average** fee of $10 per ton would raise about the same annual revenues as CERCLA presently does. If total waste generation is much higher, as it may be because of a broader universe of waste regulated by States (see ch. 4), or if more wastes are brought under the RCRA program, then fees might be reduced somewhat.

For disposal and dispersal options, with high fees of perhaps $10 to $20 per ton, costs could increase by less than 10 to 40 percent for a disposal cost range of $50 to $200 per ton, and perhaps by less if the national waste stream is found to be much greater than the currently used figure (see discussion in later section). However, for high-volume, low-hazard waste disposal or treatment may only cost $10 to $20 per ton, and fees should be lower than the average.

Table 11 illustrates a waste fee system that has been proposed in Minnesota. The structure of this system is strongly biased against land disposal, particularly for liquid waste. It also favors onsite over offsite management, a bias often defended on the basis of advantages associated with not transporting hazardous materials, rather than on any intrinsically superior level of management at onsite facilities. This system, it should be noted, is also simple. The use of relatively simple generic waste categories for different fee rates is necessary to facilitate administration of such a system.

Table 11.—Illustration of a Hazardous Waste Generator Tax Structure

Waste management category	Tax on solid waste ($/metric ton)	Tax on liquid waste ($/metric ton)
Land disposal	42	85
Offsite:		
Land disposal after treatment	21	42
Treatment	11	21
Onsite:		
Land disposal after treatment	11	21
Treatment	5	11
Recycling/reuse; used crankcase oil	0	0

NOTE: In addition to this tax, to support a State Superfund, a hazardous waste generator fee (a minimum fee plus a fee dependent on the quantity of waste generated) was also proposed to support State administrative costs for hazardous waste programs. A provision was included to exempt small generators.

SOURCE: Minnesota Conference Report H.F. No. 1176, Mar. 19, 1982.

New York State employs a simple system, with the following rates imposed on waste generators: $12/ton for hazardous waste disposed of in landfills; $9/ton for waste treated or disposed of offsite, excluding disposal in landfills; $2/ton for waste incinerated or treated onsite; and no fee on waste subject to resource recovery. Unlike the Minnesota system, the New York fee structure is based only on management choice, and does not deal with the degree-of-hazard of the waste. However, it too provides an incentive for onsite management, but to a lesser degree than the Minnesota approach.

Hazardous waste generators in California are covered by two separate fee systems: one supports the operation of the overall State hazardous waste program and imposes a $4/ton fee for wastes that are land disposed (with a limit of $10,000 per month); the other is a State Superfund system that uses a a current base rate* of $6.52/ton for hazardous wastes that are land disposed, a rate twice that of the base rate, or $13.04/ton currently, for extremely hazardous wastes that are land disposed, a rate that is 15 percent of the base rate for wastes placed in surface impoundments and for wastes regulated as hazardous by the State but not under the Federal RCRA program, and a rate of 0.1 percent of the base rate for relatively high-volume, low-hazard mining overburden wastes. While the California system recognizes varying hazard levels of wastes, it places no fees whatsoever on any wastes for which the management choice does not involve the use of the land. Thus, there is an incentive to use waste treatments rather than land disposal, but (unlike the Minnesota and New York cases) it provides no direct incentive for waste reduction nor for onsite rather than offsite management.

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*There is a view in industry that characterizing recycled hazardous materials as hazardous waste is inappropriate, because they are not discards. However, it is also argued by others that it is necessary to keep such materials in the category of waste because there is still a potential for releases of hazardous constituents during handling, transport, and recycling of such materials. Moreover, there is the likelihood that not all generators of such materials will recycle them, and that those who do recycle them will not always do so.

**In this regard, the use of deposit-refund types of economic incentives offers a unique advantage. The user of a feedstock, that leads to generating a hazardous waste, pays a deposit that is returned only on transfer of the waste to an appropriate management facility. This approach provides a direct economic incentive for proper management, and is being used very successfully in West Germany for ensuring the recycling of waste oils. In contrast to a waste fee approach, in which some parties may be motivated to escape by illegal action, the deposit-refund approach makes improper behavior costly, even without enforcement actions.

The underlying philosophy of the waste-fee system approach is to reward those who minimize future risks and costs to society through the use of environmentally preferred alternatives. As existing uncontrolled sites are cleaned up, future uncontrolled sites made less likely, and hazardous waste generation reduced, the fees on non-land-disposed wastes could be decreased. Morever, such an incentive system would encourage efforts to reduce the amounts of waste generated. The uses of the fees collected could be expanded, as has been recommended,[29] to deal with injuries and damages directly associated with mismanagement of hazardous wastes. Fees could be collected by States, and it might be advantageous to distribute a specified percentage of those collected by a State to the State program. This could promote the replacement of varying State fee programs with a uniform national system, at least for federally regulated wastes. Such a uniform system could minimize potential effects on interstate commerce, including the transport of waste to, or the location of waste generators in, States with low fees or none at all.

Capital Needs.—A major obstacle to the adoption of measures to reduce waste generation or hazard levels is the need for capital investment for new or modified equipment or facilities, either by waste generators or commercial waste managers. A **Federal loan program** could be instituted, which offered low interest rates, and perhaps long terms for repayment, for capital expenditures on existing or new facilities directly related to waste or hazard reduction. Alternatively, the Federal program might guarantee private sector loans, or make available tax free bonds to finance loans. Technical guidelines could be established and the administration of loan evaluations and approvals could be shifted primarily to the States. Unexpended CERCLA funds, either those under the present program (which are currently quite large) or more likely under a new program as described above, might be used as a source of funds for loans. A fixed fraction of such fee-generated funds might be designated for these types of loans. One recent study which examined using government loan incentives for resource recovery equipment in the electroplating industry concluded that such a program could be quite effective.[30]

Another means of addressing capital needs is the use of **tax credits.** A special, time-limited investment tax credit to spur capital investments could be offered if directly related to reduction of waste or hazard levels. Although this is a traditional approach to achieving a desired goal of society, it has received criticism because of the loss of revenues to the government. However, the case of hazardous waste presents a particularly good example of how spending promoted by a tax benefit could, in the long-term, markedly reduce government expenditures. Moreover, a special tax credit of 10 percent (in addition to any broad investment tax credit) likely would lead to reductions in government revenues of at most several hundred million dollars annually over a 5- to 10-year period. An interesting possibility would be to use some fraction of the fees collected to compensate the Treasury for all or part of the lost tax revenues. The electroplating industry study also concluded that a special investment tax credit for resource recovery investments could be effective.

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*This base rate is adjusted annually, on the basis of changing amounts of wastes generated and the distribution in the different wastes classes that are taxed, so as to produce a total of $10 million annually for the State Superfund.

[29] "Injuries and Damages From Hazardous Wastes-Analysis and Improvement of Legal Remedies," a report to Congress in compliance with sec. 301(e) of CERCLA, September 1982. (By an independent group of attorneys.)

[30] "Hazardous Waste Management in the Great Lakes Region: Opportunities for Economic Development and Resource Recovery" (Washington, D.C.: U.S. Department of Commerce, National Bureau of Standards, September 1982).

A number of States have used tax incentives to deal with capital needs for improved hazardous waste management. Some examples have been noted in a recent study.[31] Wisconsin exempts machinery and equipment used for treating hazardous waste from the State property tax. North Carolina excludes real estate and equipment used for waste disposal and resource recovery from its property tax and it also offers accelerated depreciation on resource recovery equipment. Michigan exempts from property taxation the value of any improvements in old facilities for the purpose of waste reduction. Oregon offers a 100-percent tax credit for pollution control facilities associated with recovery of energy or of substances with economic value. However, it is not yet clear how their programs have influenced waste management decisions.

Assistance for R&D Efforts.—Alternatives to disposal and dispersal meet another obstacle in that technologies such as process modification or for treatment of particularly difficult wastes require applied R&D efforts before becoming commercially feasible. Increased Federal support of private sector R&D, including pilot plant efforts, could be very useful. Relatively small sums might produce very large benefits. In order to allay objections to using Federal funds, it might be possible to structure R&D assistance so as to recover the Federal investment, perhaps through long-term, low-interest loans to be repaid upon successful commercialization of the technology. Profit sharing and exclusive licensing arrangements with payments to the government are also possible. Illinois commits a portion of the revenues obtained from fees on waste for R&D projects.

Benefits of the Option

To what extent would adoption of government incentives for using alternatives to hazardous waste disposal and dispersal achieve the eight policy goals? An intrinsic merit of this option is that congressional action could be taken in the near future, and implementation could also take place within a few years, with a goal to replace the current system of collecting fees under CERCLA which expires in 1985.

GOAL 1

Improve protection of health and the environment without undue delays and uncertainties.

Major benefits could result from lowering of the probability of releases of hazardous constituents into the environment (assuming adequate regulations and enforcement for treatment alternatives to land disposal). Implementation of this option would not interfere with the existing regulatory program. The main effect would be to shift regulated parties out of the regulatory system when they no longer produce waste, or to shift the type or extent of regulation because generators produced different amounts or types of waste that required different waste management options. It would become preferable to be regulated as a recycling or energy recovery facility, with a minimal reporting requirement, rather than as a disposal facility.

GOAL 2

Expand universe of federally regulated hazardous waste.

This option does not address this goal. Any effects would be indirect and difficult to predict.

GOAL 3

Encourage alternatives to land disposal.

This option's major benefit would be to achieve this goal as much as any public policy could. However, economic incentives for alternatives to disposal and dispersal should not lead to a relaxation of the current regulatory program. Stringent regulations and effective enforcement would still be required.

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[31] "A Survey and Analysis of State Policy Options to Encourage Alternatives to Land Disposal of Hazardous Waste," National Conference of State Legislatures, July 1981.

GOAL 4

Improve data for risk assessments and RCRA/CERCLA implementation.

A moderate benefit might result, since the fee system could provide motivation for the collection and continued maintenance of complete and reliable data on waste generators.

GOAL 5

Improve and expand RCRA/CERCLA participation by States.

Insofar as the fee system would contribute to funding for both the Federal and State programs, a major benefit relative to this goal could result. The administrative burden placed on the States could be reduced, as less waste and fewer waste generators would be regulated. Although there could be an increase in State activities from the administration of an incentive program, adoption of a Federal fee system could remove the burden of existing State fee systems while providing greater revenues because of a broader range of waste regulated. A recent study of State fee systems, most of which have not been in effect very long, concludes that relatively small sums are being collected, with only 5 States having fees imposed on waste generators, 14 with fees on transporters, 18 with fees on waste management facilities, and 17 with no fees and no desire to implement any.[32] However, another study concluded that only 7 State hazardous waste agencies (out of a total of 18 States with any type of fee) collect and keep fees, with the others placing the fees collected in State general funds.[33] This points to a potential benefit of a Federal fee system affecting all States that provided funds for operation of State hazardous waste programs.

GOAL 6

Moderate increases in costs to governments for administration and to industry for compliance.

Clearly a waste fee system would impose higher near-term costs on waste generators, although it could contribute to a reduction in future liabilities. Governments would benefit from a source of funding for administering their hazardous waste programs, and from fewer facilities to regulate due to waste reduction, but would incur new costs in administration of the economic incentives program. With incentives, less waste generated, and fewer regulated facilities, long-term regulatory compliance costs in the private sector and governmental costs might decrease (although this is somewhat uncertain). Costs associated with adverse impacts on health and the environment would eventually decrease because of lower waste generation, reduced hazard levels of wastes, and use of management options that could permanently remove risks.

GOAL 7

Reduce risks transferred to the future; reduce costs of management shifted to society in general.

There would be a major benefit associated with decreases in the amount of hazardous waste generated and placed in the environment, as well as in the hazard levels of wastes ultimately disposed in the environment. Greater internalization of costs would result because the waste fee system would transfer the liabilities associated with possible future releases, remediation actions, and possibly compensation to waste generators.

GOAL 8

Reduce public concerns over the siting of facilities.

Because most public concern is focused on problems of land disposal, this option offers a major benefit through its objective of shifting waste management from land disposal. Moreover, greater public attention to alternatives would promote better understanding of the differences between land disposal and the various alternatives, and of corresponding differences in type and probability of releases. Moreover, an ensured means of funding State programs could improve public confidence in the effectiveness of such programs.

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[32] "A Study of State Fee Systems for Hazardous Waste Management Programs," U.S. EPA, July 1982.

[33] "The State of the States: Management of Environmental Programs in the 1980's," National Governors' Association, June 1982.

Costs and Problems for Implementation

Until specific incentive programs are developed, it is impossible to estimate protracted administrative costs. However, the incentives considered above have been chosen because, for the most part, they would not lead to substantial outlays of budgeted Federal funds. Additional funds for EPA to perform analyses and devise a plan during a 2-year period might be about $5 million,* including funds to work with the States to assess their involvement.

It may be suggested that other nonregulatory approaches to providing incentives for alternatives to land disposal exist and are more effective than a fee system. Two others frequently considered are based on the legal system and on insurance procedures. The essential problem with relying on the legal system concerns uncertainties of the system. Waste managers must perceive a high probability of costly legal damages from release of hazardous constituents. In the absence of such perception, reliance on government enforcement actions or private party suits to return previously externalized costs to waste managers is uncertain. Legal findings and judgments in the procedure also introduce uncertainties. While current environmental statutes may facilitate legal actions, and enforcement efforts may be somewhat effective, there is little evidence to suggest that legal approaches can provide expedient and widespread feedback effects for waste management choices.

RCRA's financial liability requirements have already increased the use of insurance options. Here too there are considerable uncertainties over whether such distribution and assessment of risks is expedient in affecting management choices. There are very few actuarial data to assist insurance firms in structuring costs, little experience with such claims, and considerable difficulty in making risk assessments of facilities. As with reliance on the legal system, insurance approaches offer more remedial than preventive benefits for hazardous waste release. However, use of the legal and insurance system are necessary and should be viewed (as should the regulations themselves) as complements to a fee system.

There are few concerns over the use of loan guarantees or tax credits, and assistance for R&D efforts, particularly when compared to the more far-reaching use of a Federal fee system. The most frequent argument against the use of economic incentives is that they would require significant administrative efforts. While this is true, increased government resources needed to administer an incentive program, in terms of numbers of workers and skills required, could result in a net advantage. Because of an anticipated reduction in both waste and management facilities requiring regulation, fewer **technically** skilled personnel would be required.

Opponents of a Federal fee on generated wastes also raise the problem of inadequate capacities for land disposal alternatives. However, there is evidence that available facilities for such alternatives have substantial unused capacities.[34] And if waste is reduced at the source such obstacles are overcome. One of the most critical factors associated with adequate capacities for alternatives to land disposal involves investments by the waste management services industry or waste generators. Such investments by the private sector to build more facilities are unlikely when bias in the Federal program continues to contribute to lower costs for land disposal options. A Federal fee system could provide (particularly if announced some time before implementation) the necessary certainty for the private sector investment in facilities.

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*The basis for this figure and for the estimated costs for options IV and V is based on OTA's estimate of the level of effort and typical costs as follows: an average cost of $100,000 per senior professional per year, including $60,000 for compensation, $20,000 for administrative support, and $20,000 for research support. Also, these estimates are consistent with EPA's costs for performing major analytical efforts such as regulatory impact analyses that have had an average value of $373,000 ("Improved Quality, Adequate Resources, and Consistent Oversight Needed If Regulatory Analysis is to Help Control Costs of Regulations," GAO, November, 1982.)

[34] For example, in a recent study for EPA of nine major offsite, commercial waste management companies, capacity utilization for incineration decreased from 83 percent in 1980 to 78 percent in 1981, for chemical treatment from 49 to 56 percent, and for resource recovery it remained constant at 24 percent. ("Review of Activities of Major Firms in the Commercial Hazardous Waste Management Industry: 1981 Update," Booz-Allen & Hamilton, May 7, 1982.)

Results concerning the technical and economic feasibility of offering alternatives to land disposal from a California study are encouraging:

1. 75 percent of the hazardous waste disposed of in the most secure landfills could be recycled, treated, or destroyed;
2. most additional waste management capacity needed to recycle, treat, or destroy waste could be developed in less than 2 years; and
3. the additional cost of recycling, treating, or incinerating highly toxic waste would have a minimal effect on industry.[35]

Another California study concludes that new plants would produce half the hazardous waste currently produced by similar activities.[36] This indicates the potential for waste reduction efforts, even in existing plants.

Another ongoing study concerned solely with hazardous waste reduction at the source concluded "estimates of the impact on the toxic waste problem through reduction at source range from 30 to 80 percent—an exciting challenge and opportunity that deserves nationwide attention."[37]

If a Federal fee system is chosen by Congress, it would most likely replace the current scheme used under CERCLA. While there might be broad public support for this approach, opponents quickly point out that increased fees on waste generators could be burdensome to industry. There is the prospect of reduced profits and failure of marginally successful establishments, unless the added costs of waste management were passed on to the ultimate consumers of the products. However, some evidence exists that additional costs to consumers would be small, as waste management costs probably contribute at most only a small percentage (probably 1 to 3 percent) of the costs of production or of final prices. Even a high fee on land disposal of waste would, therefore, not affect final prices substantially. There is also some evidence that increased costs to consumers related to improved protection of health and the environment would be acceptable.*

Another concern is that a Federal fee system could prompt more illegal dumping of hazardous waste. However, as has already been noted, effective enforcement efforts always remain a necessity. Control of illegal dumping, moreover, is not merely a matter of regulatory enforcement—the issue is effective "policing" efforts, since illegal dumping of hazardous waste is now accepted as constituting criminal behavior.

It has been suggested that it would be possible to rely on the States to adopt such an approach, it is not realistic to believe that all the States will or can do so, or that they will adopt similar programs. In order to achieve consistent and equitable treatment of hazardous waste generators nationally, and to avoid the formation of "pollution havens" in States without such fees, a Federal system is appropriate. The reasoning is essentially the same as that used to first justify the creation of the Federal hazardous waste regulatory system.

However, **it may be effective to have the States administer a Federal fee system.** States are in the best position to obtain and maintain information on waste generators and their management practices. It would help offset the States' concerns that they would be required to dismantle their fee systems, at least for federally regulated waste. Some States may find a Federal fee system more acceptable if they were assured a key role in its administration and use of some fee revenues for support of State programs. Having a reliable source of funding for State programs is an important issue. EPA has indicated its desire to reduce or eliminate grants to the States. To compensate for this loss of revenues, EPA is encouraging the use of State fee systems as well as a variety of fiscal approaches for States to obtain the required matching funds for Superfund cleanups. However, the latter, such as sale-leasebacks of State assets, use of State bonds, and lease-purchases, present problems of loss of tax revenues, administrative difficulties, and uncertain gains in funds.*

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[35] California Office of Appropriate Technology, "Alternatives to the Land Disposal of Hazardous Wastes: An Assessment for California," 1981.

[36] "Future Hazardous Waste Generation in California," Department of Health Services, Oct. 1, 1982.

[37] Joanna D. Underwood, Executive Director, Inform, *The New York Times*, Dec. 27, 1982.

*A recent major opinion survey on public support for environmental legislation found that 60 percent interviewed favor giving priority to environmental cleanup "even if companies have to charge more for their products and services." (As reported in the Washington Post, Nov. 11, 1982.)

Some may believe that any fee on hazardous waste should be placed on management facilities rather than on waste generators. For onsite waste management there would be no difference. However, for waste managed offsite placing the fee on facility operators may not achieve the intended goal of influencing waste reduction and treatment choices which are or should be made by generators. For example, facility operators may not pass the fee on to waste generators, may vary the amount passed on among generators, or may cut waste management costs (and its effectiveness) to offset fees in order to gain advantage over competitors. For facilities performing a variety of operations (recycling, treatment, and disposal), there may be an incentive to misrepresent the amounts of waste managed in those ways with the highest fees. Finally, with a fee imposed on facilities there may be pressure to levy the fee on the basis of the rates charged (usually a percent) and perhaps only for offsite operations. However, such an approach has the counterproductive effect of making facilities more attractive than they already are because of lower costs resulting from poorer design, operations, or monitoring capabilities. Moreover, there is no reason to remove onsite facilities from the fee system; with the exception of waste transportation, they present the same problems and potential costs to society as offsite facilities and, most importantly, account for most of the hazardous waste managed.

If a waste fee system is used to generate funds used for CERCLA activities, should the entire burden of the past be borne by present waste generators? This same concern applies to the current CERCLA funding mechanism. **It can be argued that shifting fees from feedstocks to waste is probably more equitable, since there is no certain link between feedstocks and waste generated or mismanaged.** A partial remedy would be to continue present procedures, and to use general Federal funds to contribute to CERCLA costs. Nevertheless, it must be anticipated that those industries generating large amounts of hazardous waste will find a new Federal fee on them objectionable.

A legitimate concern is that a successful fee system would eventually reduce the amount of waste generated, thus requiring increases of fees on remaining waste in order to maintain funds for all the purposes already discussed. This situation might motivate government to unnecessarily bring more waste under regulatory control. On the other hand, waste generators could be more motivated to attempt to have their waste delisted. Another possibility is that generators would concentrate their wastes, lowering fees, but increasing waste hazards. There are no simple solutions to these potential problems. It is unlikely, however, that waste reduction efforts would be so rapid or extensive that the amount of waste generated nationally would fall so low that fees on remaining waste would become unacceptable. Some calculations, based on simplified but realistic assumptions, are shown in figure 3 to illustrate possible fee levels and changes over time, while maintaining total revenues. A fig-

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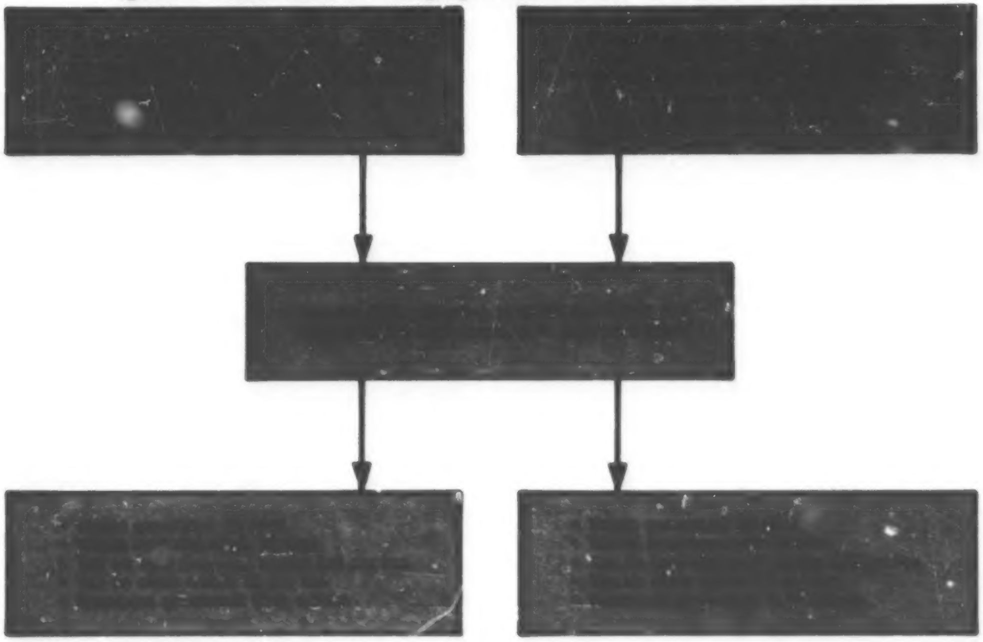
*EPA's study on "Increasing Purchasing Power of State Funds for Hazardous Substance Response," is expected to be completed in the Spring of 1983. It is concerned with the inability of States to obtain the required matching funds for CERCLA cleanups. In early drafts it is noted that 22 States, accounting for two-thirds of the sites on the National Priority List, have a continuous, reliable method of financing remedial actions. But "the vast majority of these States have raised less than one-fourth of the estimated matching monies needed."

Figure 3.—Illustration of Changing Federal Waste Fee System Over Time



SOURCE: Office of Technology Assessment.

ure of $650 million has been used in this illustration because it approximates what would be required to fund current CERCLA activities, fund State hazardous programs, and provide some limited funds in the victim compensation area.* Over time, the system likely would reach some equilibrium (including reduced manufacture and consumption of products associated with hazardous waste generation), and fees would be reduced because of less administration of the programs and less cleanup of uncontrolled sites.

Lastly, there are potential indirect economic effects that are difficult to predict. There might be a negative effect on the international competitiveness of U.S. exported products because of increased costs brought about by fees. There are ways to minimize or prevent such problems. Provision of capital and R&D assistance to waste generators enables them to reduce waste, and thereby eliminate waste fees. Proposed fee systems should be announced sometime before implementation so that industries could anticipate increases in costs and take appropriate actions in time. Finally, the government should increase efforts in the international community (through, e.g., the Organization of Economic Community Development and the United Nations) aimed at educating foreign governments about the long-term benefits of improved hazardous waste management, although European practices to a large extent already rely more on options other than land disposal. With regard to imports that might achieve some competitive advantage in the domestic market because domestic manufacturers are paying a hazardous waste fee, it has been suggested that (in addition to the remedies noted above) some type of import duty or fee equivalent to what domestic manufacturers pay could be levied. However, this could be objected to on the basis that it represents a form of trade protectionism.

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*Use of waste generator fee revenues for any victim compensation use raises a number of issues. There is a concern that claims related to personal or property damages could be "unbounded" and that waste fees might be raised continually to generate sufficient funds for this purpose. While there may be a need for provide funds for victim compensation, it is generally understood that it is extremely difficult to prove scientifically the causal link between a hazardous waste condition and some personal or property damage. Thus, there is concern that very large claims could be made on the basis of some type of "no-fault" approach.

In addressing the legitimate concerns of those most affected by imposition of fees, it is important to recall the underlying principle of the fee system: **those who are responsible for generating hazardous waste (both generators and consumers) should pay for the proper management of the waste, government activities that may be needed to clean up such wastes, and for the damages to health and the environment that may ultimately result from such waste.** Moreover, a fee system that affected consumer prices could lead to a more balanced public perspective of hazardous waste. The demand by the public for generators to apply more stringent and costly controls would be balanced by the need of the public to consider the "hazardous waste-intensiveness" of products. It should also be noted that even treatment alternatives to land disposal pose some risks to both health and the environment and, hence, there is justification for fees on waste so treated. No technology used to manage hazardous waste can guarantee zero release of hazardous constituents (see ch. 5).

Some argue that imposing fees on hazardous waste would cause price distortions in the marketplace, but use of a fee system can be viewed as a remedial policy action required to correct both an economic distortion and an inequity already existing in the marketplace. The market currently shifts risks and costs to people (now and in the future) not directly deriving the benefits from products or services causing the risks and costs. Yet management choices under a fee system could affect the competitiveness, success, and failure of individual firms resulting in distributive or geographic economic effects. The varying abilities of firms to adjust to a fee system requires the need for policymakers to evaluate appropriate community and worker adjustment programs, and to include means to address the capital and R&D problems examined earlier as complements to a waste fee system. By anticipating the need for capital and R&D assistance, it would be possible to minimize adverse economic effects on industry.

Option IV
Development and Potential Use of a Hazard Classification Framework

This option provides for the development and assessment of a hazard classification framework for risk management that if feasible and beneficial, could be introduced into the RCRA regulatory program. The framework would be based on detailed technical criteria establishing several different ranges, or classes, of hazard levels. There would also be a corresponding classification system for facilities to deal with risk management. The waste and facility classification would provide the means to:

1. set priorities, such as determining what areas need to be addressed first in obtaining more accurate and reliable data;
2. establish different levels of monitoring requirements; and
3. establish appropriate levels of regulatory control, including restrictions on certain technologies and facilities, exemptions from full regulatory coverage, and different levels of performance standards for RCRA regulations covering the operation of waste management facilities.

Although using classifications seems to suggest considerable complexity and drastic changes in the regulatory structure, neither is required. What is envisioned is a means to structure the evolving RCRA regulatory program by improving its scientific base. For example, some solid wastes regulated under subtitle D of RCRA would be brought under subtitle C control, but, for almost all these wastes, there would be minimal regulatory requirements (e.g., reporting and notification requirements). Similarly, some low-hazard waste currently under subtitle C might receive less regulation than they now receive, and perhaps some removed from the hazardous category altogether. Some high-hazard waste would receive more stringent regulation. For most hazardous waste, however, the classification approach would have little effect.

Congressional action could be accomplished by amendment to RCRA, by initially directing EPA, or another agency, to develop a waste and facility classification system and a plan for its implementation. Such an analytical effort could take several years and would require additional Federal appropriations of perhaps $5 million to $10 million.* Presumably, no new data would be acquired for this initial study phase (for which health and environment effects data is an expensive undertaking), but rather existing data bases would be used. The second level of congressional action would consist of an evaluation of the study, and a decision: 1) to either move ahead with implementation; 2) to pursue a second, more detailed study, possibly involving the acquisition of new data, followed by integration of the hazard classification framework into the RCRA program; or 3) to discontinue the option. Implementation, or a second study, could take several years, and the costs are difficult to estimate.

In the following discussion, the elements of this option are summarized. The appendix to this chapter contains a detailed discussion of one approach to using waste and facility classification. No attempt has been made by OTA to design an actual classification system; those now available are discussed in chapter 6. Second, the option is evaluated relative to the eight policy goals described earlier. Third, the costs and problems of implementation are discussed.

Brief Summary of a Hazard Classification Framework

The key elements of this particular application of the hazard classification concept are presented in figure 2. The approach is compatible with the hierarchy of alternative management strategies presented earlier, particularly with the goal of reducing the amount and hazard level of wastes.

Elements of the Approach.—Several important elements, each requiring reliable information to be obtained by the Federal program, form the basis of this scheme. Some of the information may be currently available in varying degrees of completeness and accuracy. The collection of other necessary data may require substantial effort. There are three elements of the system:

1. **The critical characteristics of those constituents of the waste that largely determine its hazard classification.**—Classifying waste is a major undertaking that requires a careful analytical framework and substantial amounts of information on a very broad variety of factors, including: concentrations of hazardous constituents, toxicities, their mobility through various environmental media, environmental persistence or bioaccumulation, and various safety characteristics. It is not sufficient to merely use information on the most hazardous constituent, or the one present in the largest amount, to fully assess a particular waste. There is currently no standard procedure to describe the hazard level for a physically and chemically complex waste, although there are indications that it is technically feasible to develop one (see ch. 6).
2. **Consideration of those factors used to determine facility classes.**—
   a. **The chemical and physical characteristics of the waste that limit treatment and disposal options.** This information would indicate whether the waste is aqueous or nonaqueous, inorganic or organic, and whether it is a liquid, sludge, or bulk waste with a high solid content. It also would be necessary to know if the waste contains toxic metals, known toxic organics, corrosive acids, explosives, or highly ignitable substances.
   b. **Information on the broad range of technology options that are commercially available and technically feasible.** Considerable information is needed on the designs of technologies, actual performance characteristics, problems related to operation and maintenance, and requirements for

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*The total EPA fiscal year 1983 R&D budget related to hazardous waste is about $30 million. Thus, $10 million over 3 years would amount to 11 percent of EPA's hazardous waste R&D budget.

trained personnel. Problems related to patented and proprietary information may have to be addressed.

c. **Performance standards for various technology options, used for setting the level of effectiveness (risk reduction) of the technology, or the level of acceptable release of hazardous constituents from the facility.** For waste treatment operations, performance standards may be given in terms of changes to be effected in various critical characteristics of the waste. After incineration, for example, the percent of one or more waste constituents destroyed, perhaps in conjunction with acceptable levels of emissions, can be used. (This is similar to what is used now.) It is important that waste classification and its linkage to facility class be technically sound in order to avoid "technology forcing" when, in fact, available technology can achieve desired levels of protection. For disposal operations, performance standards may be given in terms of acceptable levels of release over specified periods of time. Standards would vary with levels of hazard.

   In general, different types of performance standards will be required for different technologies and may be required for different levels of hazard. Selection of performance standards depend on the regulatory functions that are deemed most important. What is attractive from the perspective of ease of enforcement or compliance may not be as attractive to those concerned with risk management.

3. **Matching of waste and facility classes.** —This is the key step—ensuring that levels of risk are consistent across both waste and facility classes. For a particular waste class, different technologies within the same facility class should offer similar risks.

How Classification Differs From Other Approaches.—The framework described involves no new concepts. Rather, it integrates known facts and principles into a framework for government management and regulation of hazardous waste. The phrase "degree of hazard" does not necessarily imply the use of hazard classification. In this classification approach, common characteristics are assigned values and are used to group wastes and facilities so that those within a group have similar characteristic levels of hazard and control. Neither does such an approach imply the use of fixed, rigid categories. New information or changes in policy can affect the definition of new criteria, redefining the classes in the system.

It must be emphasized that all suggested uses of hazard classification assume that **only a few classes would be required and are practical.** Usually envisioned are high, medium, low, and no hazard (essentially a decision to consider the waste as an ordinary solid waste) waste classes and with corresponding facility classes. Therefore, the classification approach is more a "coarse tuning" than a "fine tuning" that may be achieved through risk assessments of individual wastes and facilities. Compared to the broad range of variations possible with current permitting decisions (for land disposal options, rather than for treatment facilities), the classification approach offers permit writers a fixed number of federally determined classes for wastes and facilities. It is possible, however, to integrate technology and site-specific factors into the use of systems based on hazard classification. A permit writer could change the classification of a waste and, consequently, the level of regulatory control required for a facility, because of technology and site-specific factors that lead to risk reductions. A facility might utilize some type of pretreatment of the waste that reduces the performance standard required to achieve acceptable levels of releases. Or the facility may be in a location in which any releases would be so dispersed prior to any exposure to a vulnerable receptor that a lower performance standard would be acceptable. Such options are limited by the number of hazard classes available and the corresponding regulatory requirements, including performance standards, monitoring requirements, and criteria for acceptable sites.

Furthermore, the classification approach, in contrast to the current program in which most wastes are considered equally with respect to regulatory requirements, implies that **better defined and substantiated** technical criteria and standards are required—a set for each hazard class. This is necessary in order to link the level of regulatory control (facility class) with distinct hazard class.

The waste and facility classification approach differs somewhat from risk assessment approaches which estimate probabilities and levels of potential harm. Although there is no standard type of risk assessment, it appears that in most likely applications, the emphasis would be on the determination of numerical levels of risks for adverse effects on health and the environment. Risk assessments usually require substantial information concerning actual situations, or at least such a focus, including how particular people or components of the environment will respond to specific types and levels of exposure. However, it is also possible to carry out risk assessments for generic categories of wastes, locations, and technologies (see ch. 8 for a discussion of risk assessment and ch. 7 for a discussion of EPA's Risk/Cost Policy model which employs this approach). Classification systems rely more on general scientific and technical information in the determination of potential and generic adverse effects for defined classes of wastes and facilities.

Classification may also be contrasted with more qualitative approaches that simply may list waste as having different degrees of hazard, without presenting clear, detailed criteria for determining such differences. The listing approach (which is used in the current program) provides little guidance for dealing with emergent future questions; it is largely ad hoc in nature. Classification approaches, on the other hand, provide consistent, yet flexible, procedures capable of dealing with new situations. While a classification approach requires greater initial investment of resources as compared to alternative approaches, it may offer more long-term benefits once developed.

Illustration of the Classification Approach.—Two types of questions are usually raised concerning the hazard classification approach. What types of data are used to distinguish different waste hazard classes? What are the regulatory implications of establishing different waste hazard classes? Table 12 provides examples of how the classification approach can be developed and used, but it is emphasized that the examples shown are strictly for illustrative purposes only and do not constitute any endorsement or recommendation by OTA.

Benefits of the Option

Benefits of the hazard classification approach are described below in terms of how **eventual implementation of a suitably examined system** might satisfy the eight goals for all policy options. A problem with this option is that a number of years are required for both analysis and implementation. Therefore, estimation of potential benefits tends to be more speculative, and there are greater uncertainties because of what might take place before the option is fully implemented.

GOAL 1

Improve protection of health and the environment without undue delays and uncertainties.

There are major uncertainties as to when a classification system might be implemented, and what would be included in such a system. Because the current program is moving in the direction of using hazard levels to establish regulatory coverage and stringency, this option can be viewed as a means of systematizing a program that is evolving in a somewhat ad hoc manner. Once a simple classification system is developed and applied, it may offer the benefit of reduced delays and uncertainties because of the availability of technical criteria and procedures which can be used to deal with new situations. The validity and usefulness of the hazard classification approach from a waste management perspective has been summed up as follows:

> One school holds that, if it is hazardous by definition of the regulation, then it should go

Table 12.—Illustrative Examples of a Potential Hazard Classification Framework[a]

Examples of scientific criteria for waste definition[b]	Examples of varying levels of regulatory control, and restrictions on waste management practices[c]
High hazard	
1) Acute toxicity: Oral rat LD_{50} < 5 mg/kg Aquatic LC_{50} < 1 mg/kg 2) Chronic toxicity: Equivalent concentration of persistent compounds > 1.0% Toxic metals 100 to 10,000 × DWS Suspected bioaccumulative carcinogens	Limited to Class I facilities; cannot be placed in surface impoundments, landfills, injection wells, land farms No monitoring exemptions Incineration DRE > 99.99; can only be burned in industrial boilers Cannot be stored more than 30 days without permit No exemptions for small generators Recycling facilities to be permitted
Medium hazard	
1) Acute toxicity: Oral rate LD_{50} 5 to 500 mg/kg Aquatic LC_{50} 1 to 100 mg/kg 2) Chronic toxicity: Equivalent concentration of persistent compounds 0.01-1.0% Toxic metals 100 × DWS Suspected nonbioaccumulated carcinogens 3) Corrosive, reactive, ignitable	Limited to Class I and II facilities; cannot be disposed above or within 5 miles of a ground water aquifer Incineration DRE > 99.9; cannot be burned in residential boilers Can be stored up to 90 days without permit Small generators exempted up to 10 kg/month Recycling facilities permitted
Low hazard	
1) Acute toxicity: Oral rat LD_{50} > 500 mg/kg Aquatic LC_{50} > 100 mg/kg 2) Chronic toxicity: Equivalent concentration of persistent compounds < 0.01% Toxic metals 100 × DWS 3) Corrosive, reactive, ignitable	Limited to Class III facilities, and to Class I and II facilities for which no reactions with wastes are likely Incineration DRE > 99.0; can be burned in industrial and residential boilers Can be stored up to 180 days without permit Small generators exempted up to 100 kg/month Only reporting requirement for recycled waste and recycling facilities

DWS—drinking water standards

[a] The examples shown are strictly for illustrative purposes only, and do not constitute any endorsement or recommendation by OTA.

[b] Source: Adapted from system in Washington; see discussion in ch. 8.

[c] Source: Office of Technology Assessment.

only to a permitted hazardous waste management facility. Another school argues that there are degrees. Therefore, different types of hazardous wastes should go to different types of facilities. I happen to believe that the last argument makes a great deal of sense. This implies that we should have different classes of disposal facilities for different classes of hazardous wastes.[38]

GOAL 2

Expand the kinds of federally regulated hazardous waste.

This could be a major benefit. One of the primary objectives of classification is to equitably and appropriately regulate waste posing different types and levels of hazard. There could be less resistance to bringing currently exempted waste under regulation if the regulatory structure accommodates low-hazard waste at a lower level of stringency.

GOAL 3

Encourage alternatives to land disposal.

A major benefit could result from regulatory restrictions and controls better matched to varying threats. Such restrictions could limit the use of land disposal to low-hazard waste or to waste that cannot be handled in any other way. A clear and consistent framework could also contribute to greater certainty with regard to markets for various management alternatives, and could make capital investments in new alternative facilities more attractive.

GOAL 4

Improve data for risk assessments and RCRA/CERCLA implementation.

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[38] H. Lanier Hickman, "Too Much or Too Little," *Waste Age*, November 1982.

A major benefit is likely, if hazard classification leads to determination of better priorities for data needs, particularly concerning health and environmental effects. A Federal classification system would also provide the impetus for establishing a national data base for hazardous waste.

GOAL 5

Improve and expand RCRA/CERCLA participation by States.

A modest benefit might be obtained. Several States have attempted to use hazard classification approaches (see ch. 6), but progress has been slow. The attempts have been simple systems, for the most part, limited both by data and resources. More generally, many States have expressed their desire to see the degree of hazard concept used systematically in RCRA regulations. Other States are likely to have legitimate concerns over the adoption of a classification system that added, rather than reduced, regulatory complexity. How "practical" it is to use the classification approach could only be resolved by a thorough study in the initial phase of this option Eventually, the option could lead to the provision of additional technical support and an improved data base for the States.

GOAL 6

Moderate increases in the costs of governments for administration and of industry for regulatory compliance.

Governmental costs might increase or decrease, depending on the extent the classification approach created institutional efficiencies, rather than technical complexities. Another uncertainty is whether the approach might lead to substantial efforts to "reclassify" waste and facilities, analogous to, and perhaps more extensive than, current delisting efforts. Compliance costs for industry would be company-specific. While many of today's management practices might be unaffected, currently underregulated waste would be regulated more stringently, while others currently overregulated would be regulated less stringently. However, long-term costs associated with health and environmental damage, remediation efforts, and compensation could be reduced because of the greater protection against harmful release of waste.

GOAL 7

Reduce risks transferred to the future; reduce costs of waste management shifted to society in general.

To the extent that this option would reduce underregulation and total exemptions of waste, and would better ensure that land disposal would be used for waste and locations for which future hazardous release were unlikely, it would offer a major benefit by reducing the probability of future release of hazardous constituents.

GOAL 8

Reduce public concerns over the siting of facilities.

A modest benefit might result if public confidence in the Federal program is improved with the perception of a more comprehensive regulatory system and a correction of underregulation of waste. The option would create a Federal role in the broad area of siting facilities by providing a mechanism for linking facility location to the hazard level of waste, the type of technology employed, and the performance standards required of the facility. However, it would not necessarily change the present situation, with the States having the primary responsibility for land use and the siting of specific facilities. There would be continued public participation in siting and permitting of facilities. The emphasis on appropriate types and levels of monitoring for facilities would also have a positive effect on public concerns.

Costs and Problems for Implementation

The major cost and problems associated with implementation of the hazard classification approach is the need to obtain an adequate data base concerning wastes, technologies, and health and environmental effects. However, there is continuing improvement of these types of data. Adoption of classifications would greatly assist in integrating available information, and in determining priorities for obtaining new data. A major objection to the approach in the regulated community might be the perceived lack of flexibility. Another legitimate concern would be that a waste with a high-hazard classification could, in a particular situation, present less of a risk than that indicated by the hazard classification. This objection could be dealt with by providing a technically sound basis for classifying facilities, and for linking facility class to waste hazard class.

Nonetheless, the classification approach does imply setting different, or more, standards and criteria than are employed currently. This is the primary tradeoff in comparison to an apparently simpler system that does not emphasize setting different levels of regulation control with respect to level of hazard. **The complexity of the current system is "hidden" in both listing procedures that are largely ad hoc in nature, and in permitting procedures which contain considerable uncertainties because of the critical role of individual permit writers.**

OTA estimates that designing a waste and facility classification system and assembling existing data on health and environmental effects, and on technological capabilities, might require $10 million over a 5-year period. One reason for this relatively small estimate is that considerable data exist, but have not been collected and organized sufficiently for the purposes of hazard classification. During this phase, there should be substantial interaction between EPA and the States.

After consensus among EPA, the States, industry, the public, and Congress with regard to the system, the second phase could take several years. Its costs are difficult to estimate, but they could be substantial. It is possible that the detailed analyses might reveal that the complexities of the system would be overwhelming, either intrinsically or because of the impossibility of reaching a consensus between the regulated community and the regulators on specifics of classification. OTA considers that an attempt to design a technically "perfect" system will lead to paralyzing difficulties, and that the task is to simplify the design without introducing a level of arbitrariness that will be unacceptable to the regulated community.

To address these concerns, it would be fruitful for the initial study to examine:

1. alternatives for translating waste hazard and facility classification into effects on regulatory control levels;
2. means to set and change boundaries that define waste and facility classes; and
3. means to arbitrate disputes concerning wastes and facilities close to class boundaries.

Option V
Planning for Greater Integration of Environmental Protection Programs

The purpose of this option is to integrate administratively (and, if necessary, statutorily) a number of existing environmental programs that affect hazardous waste management and regulation. Policies and programs that lead to inefficient overlapping regulations, gaps in regulatory coverage, and inconsistent regulations would be addressed. Insufficient integration among different programs within EPA and other executive agencies may be leading to duplication of effort or unawareness of the extent of data and technical resources available.

A number of hazardous waste activities are now regulated under different statutes. Within EPA alone several different groups administer activities related to hazardous waste. There are also programs in several other executive agencies related to hazardous waste that do not appear to be highly integrated. The language in RCRA that mandates integration with other acts has proven too inexact, and EPA's efforts in this area do not appear to have a high priority. Ocean disposal or dispersal falls under the Marine Protection, Research, and Sanctuaries Act. Some injection wells used for waste disposal fall under the Safe Drinking Water Act and some under RCRA. Hazardous waste streams destined for municipal water treatment plants fall under CWA. A number of aspects of regulating releases into the air or water from management facilities fall under the Clean Air and Clean Water Acts. Some wastes are regulated under the Toxic Substances Control Act (TSCA). A recent study for EPA concluded:

> A number of Federal statutes govern aspects of the hazardous waste problem. The statutes in combination do not cover many of the major sources and types of hazardous waste releases, however.[39]

Congressional action for this option would consist, first, of mandating a comprehensive study of integration by EPA or some other agency, including formulation of an integration plan. The second phase would consist of congressional examination of the study and plan. If deemed necessary, legislative action would then implement the plan.

The existence of overlapping jurisdiction to regulate hazardous waste activities is not necessarily counterproductive, confusing, or undesirable. The goal should be twofold: 1) ensuring that waste that might pose risks to health and the environment do not escape regulation,* and 2) promoting the integration of hazardous waste control and other pollution control with legislation so that they can support each other, consistent with the statutory requirements and goals of each program.** There is now no mechanism for ensuring that facilities disposing of similar waste but regulated under different acts will be consistently regulated, or that a facility permitted under RCRA is not **also** disposing of other hazardous waste without a permit that are regulated under other acts.*

Although both RCRA and CERCLA are managed within the same division of EPA, there appears to be little coordination of efforts between the two programs. The following three examples illustrate additional problems associated with inadequate integration in the current Federal program. In the first two examples, the problem stems, in large part, from the original congressional acts. In the third example, dealing with interagency cooperation, the problem stems from poor administrative procedures.

Three Examples of Inadequate Integration

Regulation of PCBs under TSCA and RCRA.—Ten days before passage of RCRA, Congress enacted TSCA imposing requirements on the disposal of polychlorinated biphenyls (PCBs). A recent study of the problems associated with having two regulatory programs covering a class of hazardous waste noted that "EPA, of course, is well aware that it has been administering two closely related regulatory programs (out of different offices within the agency), but the agency has made little effort to integrate them."[40] The disposal rules for PCBs under TSCA relate to concentration but RCRA regulations do not. TSCA regulations have established a separate permitting system for approved incinerators and landfills for disposal of PCBs. Relatively few hazardous waste facilities have received permits for such disposal of PCBs. Some RCRA-permitted facilities may have the technological capabilities required under TSCA to manage PCBs. The same study notes:

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[39] "Evaluation of Market and Legal Mechanisms for Promoting Control of Hazardous Wastes" (draft), Industrial Economics, Inc., September 1982.

*A particularly important example is the problem of hazardous release into the air that may not now be receiving adequate regulation. Such releases, for the most part, are not now regulated under the Clean Air Act. With regard to hazardous air pollutants, in the past 12 years EPA has listed only seven substances, promulgated final regulations for four, proposed regulations for one, and is involved in litigation to compel it to regulate the other two. EPA has noted "If the objective is to secure control of hazardous air emissions that pose a significant danger to public health, the current statutory framework needs change. The current regulatory scheme . . . fails to provide criteria for the necessary tough technical and scientific decisions." Issue Papers prepared by EPA for Sept. 20, 1982, meeting between the EPA Administrator and representatives from the National Governors' Association, released by Lewis S. W. Crampton.

**An important example is the intended use of TSCA to stop the production of new chemicals that would lead to hazardous waste too difficult to manage, and to provide an early warning of new types of hazardous waste to the RCRA program so that they can be regulated. At present, there is no indication that TSCA is serving these functions.

*Another discrepancy among the several environmental programs is the duration of facility permits; for example, RCRA permits currently are valid for 10 years, while a 5-year period exists for permits issued under CWA, although EPA has indicated its intention to change the latter to 10 years.

[40] Mitchell H. Bernstein, "PCB's vs. RCRA Hazardous Wastes—Separate Regulatory Regimes," *The Environmental Forum*, November 1982, pp. 7-11, 36.

> Under the present bifurcated system of review, however, those facilities will also have to go through a separate approval process in order to accept PCB's for disposal—a burden which may well operate as a major disincentive for the expansion of the PCB disposal market.

Another difference between TSCA and RCRA is that, under TSCA, States and local governments are less capable of enacting their own more stringent requirements for disposal of PCBs. From the perspective of waste generators, TSCA presents the problem of environmental engineers and managers in industry being forced to track two different programs within EPA. And, from the perspective of Government efficiency, within EPA there are two programs dealing with a very similar area of regulation, but headed by different assistant administrators, staffed by different technical experts and legal advisors, and making different administrative interpretations.

Liability Insurance Rules Under RCRA and CERCLA.—RCRA directs EPA to set standards for financial responsibility of treatment, storage, and disposal facilities (TSDFs). Under current rules, insurance coverage or self-insurance is required only until closure of a facility. The current requirement is for $1 million sudden occurrence minimum/$2 million annual aggregate, and $3 million/$6 million nonsudden minimum coverage. A recent study observes that:

> . . . the minimum insurance requirements set by EPA for TSDFs appear inconsistent with other hazardous substance legislation which Congress intended to complement RCRA. CERCLA or Superfund required liability insurance or self-insurance of at least $5 million for vessels carrying hazardous substances. It is unclear why much less coverage is required for hazardous waste TSDFs that may handle large volumes of waste and may be in or near densely populated areas.[41]

A second area of concern is the apparent gap in insurance regulations for closed hazardous waste facilities. Under RCRA the coverage for facilities is required until closure. For some types of facilities, particularly landfills and impoundments where wastes remain after closure, the risks may become greater after closure than during operation of the facilities. Under CERCLA there is the Post-Closure Liability Trust Fund, derived from a tax on hazardous waste remaining at facilities after closure (beginning in September 1983). Most importantly, this fund accepts full liability for the site 5 years after a disposal facility is closed in accordance with the regulations. However, if release of hazardous substances into the environment occur within the 5-year period, CERCLA does not assume liability. A gap in government-assured protection for potential impacts from release of waste, therefore, can result in two ways: 1) the 5-year gap created by RCRA and CERCLA regulations, and 2) possibly an indefinite period of noncoverage if a site is found to be leaking before the CERCLA fund assumes responsibility. Because RCRA regulations for land disposal facilities cannot guarantee indefinite, long-term protection against releases of hazardous materials into the environment (see ch. 5) these gaps in financial responsibility requirements should be addressed.

Cooperation Between EPA and the U.S. Geological Survey (USGS).—One of the greatest concerns is that land disposal of hazardous waste can result in contamination of ground water supplies. Much of the focus of EPA's land disposal regulations is on ground water protection. The technical complexities of ground water contamination, including its detection, monitoring, and remediation, pose substantial problems. Technical expertise in this area is very limited, and data are incomplete. However, the USGS has had a Toxic Waste-Ground Water Contamination program for some time that could have contributed substantially to RCRA and CERCLA regulatory efforts.

After EPA promulgated its land disposal regulations, USGS noted:

> Present technology is not adequate to develop regulations to protect the public from hazardous waste contamination in a cost effective manner. Major technical questions are yet to be answered regarding the behavior of specific wastes under different hydrogeologic condi-

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[41] Eric Nagle, "RCRA Liability Insurance Rules—Evolution and Unresolved Issues," *The Environmental Forum*, November 1982, pp. 16-20.

> tions and on the safety, suitability, and economics of restoration and disposal methods.[42]

The expertise, experience, and data possessed by USGS could serve as a greater resource for EPA's hazardous waste activities. It would be inefficient for EPA's Office of Research and Development to duplicate USGS's efforts. USGS has a number of ongoing programs that can serve the needs of both EPA and the States in implementing RCRA and CERCLA. Studies on the behavior of contaminants in ground water aimed at improving disposal methods, appraisals of existing ground water quality, and identification of areas suitable for hazardous waste disposal are some. The last effort offers a particularly attractive opportunity with regard to facility siting. USGS could pursue a program to produce a national locations map with hydrogeologic characteristics, minimizing the risks of contamination from hazardous waste facilities.

Two Steps Toward Integration of Environmental Programs

There are two phases to this option, and both should anticipate the need for effective public participation in order to address concerns over changes that might lead to delays. First, EPA (or perhaps some independent body) could develop a plan for the improved integration of programs related to hazardous waste. The plan would also focus on statutory changes required to implement a comprehensive integration, with emphasis on the permitting of facilities.* The study also should examine obstacles to integration which occur at the State level, the costs of integration at Federal and State levels, probable improvements in protection of human health and the environment, and impacts on waste generators.

The second phase would include congressional examination of the study and plan, and an examination of how administrative and statutory changes could be achieved. Congress could also examine changes in EPA organization that would be necessary to integrate, and if such integration would require legislation.

GOAL 1

Improve protection of health and the environment without undue delays and uncertainties.

The closing of gaps in coverage and greater consistency among regulatory programs could provide major benefits, without interrupting ongoing environmental protection efforts.

GOAL 2

Expand the kinds of federally regulated hazardous waste.

A minor benefit could result from closing of gaps in regulatory coverage.

GOAL 3

Encourage alternatives to land disposal.

This option does not address this goal in a significant way.

GOAL 4

Improve data for risk assessments and RCRA/CERCLA implementation.

A minor benefit could result, chiefly by better ensuring that data obtained in one program are made available to other programs.

GOAL 5

Improve and expand RCRA/CERCLA participation by the States.

A moderate benefit could result if integration resulted in improved administration of hazardous waste programs and improving the technical support of State programs.

GOAL 6

Moderate increases in the costs of governments for administration and of industry for regulatory compliance.

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[42] "Management Information Plan FY 1984," Toxic Waste-Ground-Water Contamination Program, USGS, Sept. 27, 1982.

*These statutory changes need not—and probably would not—involve integrating the various environmental laws themselves.

Compliance costs for waste generators might increase due to greater regulatory coverage, but integration would reduce future costs for both industry and government. There would be fewer government groups to deal with, simplified permitting, and simplified monitoring of facilities. Similarly, government costs of administering the regulatory program might be reduced by greater use of multipurpose data bases, reduced paperwork, and fewer field personnel. Even if direct costs were increased due to increased regulatory activities, there could be long-term reductions in the costs associated with adverse health and environmental effects.

GOAL 7

Reduce risks transferred to the future; reduce costs of waste management shifted to society in general.

To the extent that gaps in regulatory coverge would be closed, and significant hazards controlled, this option could reduce future risks substantially. At present, some hazardous wastes are certain to find their way to the lowest cost option—which may exist, in part, because of loopholes in the regulatory structure. Although such loopholes are often closed at some point, their use over time can present serious threats to future generations because conditions are created that eventually lead to high probabilities of releases of hazardous constituents. The option does not address the externalization of costs significantly.

GOAL 8

Reduce public concerns over the siting of facilities.

A substantial benefit might result if the public views the study and implementation of integration activities as a move to make government programs more effective and efficient. On the other hand, a major reorganization could also raise public concerns. Such concerns could be reduced by meaningful public involvement during the study for integration, and this participation could be ensured by including such a requirement in the congressional mandate for the study.

Costs and Problems With Implementation

Serious objections to this option are likely. There may be fears that such an ambitious goal is simply impractical and that it could cause delays in ongoing activities. If the initial study is thorough and with sufficient resources, these objections may be minimized. A detailed study over a 3-year period with funding of perhaps $5 million might be sufficient.* Having an independent organization, rather than EPA, to conduct the study may offer the advantage of greater objectivity and impartiality.

It would also be necessary to clearly establish that no new regulatory program would be instituted until after extensive congressional examination of the proposed plan, over perhaps a 2-year period, with ample opportunities for public comment. Problems could arise in the form of conflicts among congressional committees concerning changes in jurisdiction proposed in the integration plan. There might also be opposition to integration for hazardous waste from those with interests in other environmental areas.

Integration from the limited perspective of hazardous waste management may be in conflict with attempts to integrate **all** environmental protection programs. For example, EPA is now conducting a pilot study to control toxic pollutants from all sources in the Philadelphia area. This study is part of EPA's integrated environmental management program which attempts to weigh risks across air, water, and land media. However, as this OTA study has found, there are inadequate data to support such detailed risk assessments. Moveover, the integrated approach could easily tradeoff any protection from hazardous waste because of limited funding and substantial risks from other sources of pollution. There have also been attempts to develop consolidated permits for facilities regulated under several acts.

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*Several current major EPA studies, such as its risk/cost model and its study of small generator exemption, cost about $1 million to $2 million for several years of work.

Summary Comparison of the Five Policy Options

This comparison presents the relative benefits of all five options in a convenient form and is intended to facilitate the comparison of the five options apart from the consideration of costs and time involved. Options II through V can be viewed as a series of complementary actions, taken progressively over time, or as separate individual actions offering particular benefits relative to one or more of the eight goals. Moreover, while option I (status quo) and option II (modifications in RCRA) are mutually exclusive, options III, IV, and V are compatible with option I. Options II through IV appear to require approximately the same level of initial appropriations, about $5 million to $10 million each. There are, however, no means of reliably estimating longer term costs, or cost savings for government, industry, or the general public. The five options have been presented in order of increasing time required for preliminary studies and implementation. If immediacy of implementation is an important consideration for some policymakers, then clearly options I, II, and III are the most attractive.

The policy options have been compared in two ways. In neither comparison, however, has any attempt been made to demonstrate that any one option is "best," or even that one option is better than another. In addition to the eight goals, considerations of time and cost, along with specific objections to particular options, can make any option either more or less attractive.

Table 13 summarizes in brief narrative form the key advantages and disadvantages of each option. Table 14 presents an evaluation of how each option, relative to the others, satisfies each of the eight goals. This evaluation is necessarily somewhat subjective and judgmental.

Table 13.—Key Advantages and Disadvantages of the Five Policy Options

Key advantages	Key disadvantages
I. Continue current program	
• Current program stabilized and resources already invested utilized • Participation by States improved • Short-term private and public sector costs moderated	• Protection of public health and environment may be weaker than possible and desirable • Risks and costs may be unnecessarily transferred to the future • Land disposal continues to be used extensively
II. A more comprehensive and nationally consistent RCRA program	
• Protection of health and environment improved and made more consistent nationally • More hazardous waste controlled • Data base improved	• Short-term private and public sector costs increased • Progress of present program could be slowed unless additional resources are provided • Technical resources and data may be insufficient
III. Economic incentives for alternatives to land disposal	
• More waste reduction and treatment • Costs for improved protection more equitably distributed • Public concerns over siting alleviated	• Near-term costs to industry increased • Uncertain effects on firms, communities, and international competitiveness • Illegal dumping may increase
IV. Development and potential use of a hazard classification framework	
• More waste regulated at levels consistent with hazards posed • Fewer risks and less costs transferred to the future • Improved technical support for State programs	• Major effort needed to improve data base • Unnecessary complexity may be introduced • Long-term costs for implementaiton uncertain
V. Planning for greater integration of programs	
• Gaps, overlaps, and inconsistencies in regulatory coverage reduced • Reduced transfer of risks and costs to the future • Public confidence in Federal program improved	• Considerable administrative and institutional difficulties • Possible interruptions in ongoing programs • Congressional action on necessary legislative changes may be complex

SOURCE: Office of Technology Assessment.

Table 14.—Comparative Ranking of Policy Options for Each Policy Goal

Goals	Most effective				Least effective[a]
1. Improve protection of human health and the environment without undue delays and uncertainties	II	III	I	IV	V
2. Expand universe of federally regulated hazardous waste	II	IV	V	I	III
3. Encourage alternatives to land disposal	III	IV	II	I	V
4. Improve data for risk assessment and RCRA/CERCLA implementation	II	IV	I	V	III
5. Improve and expand RCRA/CERCLA participation by States	III	II	I	IV	V
6. Moderate increases in costs to governments for administration and industry for compliance	I	IV	V	II	III
7. Reduce risks and costs transferred to the future; reduce costs of management shifted to society in general	III	II	IV	V	I
8. Reduce public concerns over siting facilities	III	II	V	IV	I

Policy options:
I. Continuation of current program.
II. A more comprehensive and nationally consistent RCRA program.
III. Economic incentives for alternatives to land disposal.
IV. Development and potential use of a hazard classification framework.
V. Planning for greater integration of environmental protection programs.

[a] Least effective does not imply total lack of effectiveness; all rankings are strictly for ordering options and do not imply any absolute level of effectiveness.

SOURCE: Office of Technology Assessment.

In presenting the five policy options, OTA is aware of the need to justify additional Federal expenditures and possible increases in short-term costs to the private sector. Current public and private sector costs for hazardous waste management are substantial, approximately $4 billion to $5 billion annually. Regardless of any policy action, these costs will increase markedly in the future as both the RCRA and CERCLA programs become more fully implemented and possibly as the expected economic recovery leads to an upturn in hazardous waste generation.

The total appropriated funds for options II through V might be $50 million. This represents about 25 percent of one year's total Federal and State expenditures for hazardous waste activities. It also represents about 1 percent of the current total public and private sector annual costs of administering and complying with RCRA and CERCLA.

There are considerable uncertainties concerning long-term costs to public and private sectors for implementing options II through V. Nonetheless, there is reason to believe that both the short- and long-term costs of carrying out all four policy options may be more than offset by the potential benefits, only some of which can be viewed in strictly economic terms. The chief areas of potential cost savings are: reductions in the number of hazardous waste sites requiring very expensive cleanup and reductions in damages to people and to the environment which entail substantial costs for treatment, remediation, and compensation. Relatively small percentage savings imply substantial absolute dollar savings. For example, if all four options led to a net savings of only 1 percent in the future annual national costs associated with hazardous waste (currently about $4 billion to $5 billion and rising), the savings in 1 year would exceed the initial costs of implementing the options. It is possible that in the long term, implementation of the options could lead to considerably greater economic benefits.

Four Scenarios

As discussed in the previous section, it is possible to implement various combinations of the five policy options. The purpose of the following discussion is to illustrate four such combinations. The scenarios have been developed by making certain simplified assumptions about varying perspectives on the need and methods for improving the current Federal program.

SCENARIO I

Current RCRA regulations are adequate, but alternatives to land disposal need encouragement. Options I and III are adopted.

Many believe that the current RCRA regulations are satisfactory and should be given an opportunity to prove themselves effective. Changes in the regulatory program, they argued, are unnecessary and counterproductive to the extensive efforts made since the passage of RCRA. Nonetheless, it is also generally recognized that from a long-term perspective, unnecessary risks and costs may be transferred to the future by disposing of many hazardous wastes in the land. There is equal concern that congressional action in this critical period of development should be expeditious and well defined.

Accordingly, this scenario consists of adopting option I (maintaining the current RCRA regulatory program) and also adopting option III (providing direct economic incentives for alternatives to land disposal). Option III is compatible with option I, since it involves nonregulatory "market" methods of reducing future releases of hazardous constituents. Option III consists of three critical components:

1. a system of fees or taxes on waste generators (to replace the current funding mechanism for CERCLA) based on quantity of waste, level of hazard, and management practices, in order to promote choices of alternatives to land disposal;
2. methods for meeting the capital needs of waste generators and commercial facilities that are initially required in efforts to reduce waste generation and to implement treatments reducing hazard or volume levels; and
3. support for R&D efforts that may be necessary before waste and hazard reduction can be accomplished commercially.

SCENARIO II

Specific changes are needed to strengthen RCRA, and an effort is needed to integrate and streamline the entire Federal hazardous waste program which has evolved in a piecemeal fashion. Options II and V are adopted.

The choice of option II is based on the desire to improve the existing RCRA regulatory program. The specific actions included in option II would close a number of existing gaps in regulatory coverage of waste, restrict certain waste from land disposal facilities, introduce more technical criteria to set nationwide standards, improve the delisting process, and would introduce limited class permitting. However, to address broader concerns over gaps, overlaps, and inconsistencies in regulatory coverage, option V would also be adopted. Option V moves beyond the analysis of RCRA regulations to examine problems related to insufficient integration between RCRA and CERCLA, among the various environmental protection statutes, and among the various executive agencies having programs associated with hazardous waste. These two options combine both short- and long-term approaches to obtaining a more effective, efficient Federal hazardous waste program.

SCENARIO III

The current RCRA program needs improvement and a nonregulatory approach is also needed to shift waste management choices away from land disposal toward waste reduction and treatment efforts. The most expeditious congressional actions are required. Options II and III are adopted.

Option II would result in the improvement of RCRA regulations to better provide short- and long-term protection of health and the environment. However, uncertainties concerning the effect of the regulations on shifting management choices away from land disposal, along with enforcement problems, would probably remain. To complement the regulatory approach of option II, option III is used to introduce direct economic incentives for alternatives to land disposal. The combination of these options would reinforce the connection between RCRA and CERCLA. Federal fees on hazardous waste, increased for land disposal and for waste with high-hazard levels, can be used to fund CERCLA and State hazardous waste programs. With a fee system, full lifecycle costs of waste management could be internalized by increased costs to responsible parties and to consumers of hazardous waste-intensive products.

SCENARIO IV

The current RCRA regulatory program should be maintained, but some long-term efforts to improve the program should also be pursued. Adopt options I, IV, and V.

Options IV and V are compatible with the current program in the near term, since both involve initial studies before changing the current program. The introduction of hazard classification at some future time does not imply any fundamental change in the RCRA regulatory structure. Similarly, a plan for regulatory integration resulting from option V would not require a restructuring of RCRA regulations. Both options IV and V can be viewed as evolutionary refinements of the current program, and their adoption would not jeopardize the stability of the present program.

Appendix 3A.—Hazard Classification in a Risk Management Framework

In the past 6 years, EPA has attempted to design a regulatory structure responsive to a variety of wastes, hazards, and treatment/disposal methods. A review of the evolution of regulations suggests that different approaches were considered by the two administrations (Carter and Reagan). For the most part, the EPA framework has considered each element of risk management in a piecemeal way. There has been an absence of integrated data on waste composition, environmental fate of waste constituents, and technological alternatives for treatment and disposal. Although this approach resulted in the promulgation of regulations, the issue of how best to respond to varying hazard and risk levels is not yet settled. During the congressional consideration of RCRA, the degree-of-hazard concept received considerable attention, but EPA was not required to use it.

To date, various lists of wastes have acknowledged different hazard levels to only a limited degree. Various aspects of the regulations also acknowledge different hazard levels. The need to "tailor" RCRA regulations to varying hazard and risk levels is seen clearly by EPA. The best approach, however, remains an area of debate. Recently, EPA has pursued a risk/cost approach (discussed in ch. 6 and its appendix) toward implementing the degree-of-hazard concept in a more comprehensive and formal way.

The purpose of this discussion is to examine in more detail the use of hazard classification as a key component in a comprehensive risk management framework that would offer a means to "fine tune" RCRA regulations.

The Need for Using Degree of Hazard

In reviewing the problems discussed in chapter 6, two general issues have emerged:

1. The regulations have been developed in general, nonspecific terms in recognition of the broad variety of wastes and the site-specific nature of facilities to be permitted.
2. For regulations that do not recognize differences among hazards and risks, tradeoffs must be made between ensuring appropriately stringent regulations for waste with highest hazards and incurring unreasonable costs for managing less hazardous waste. Thus, in the long run, medium-hazard waste may be regulated adequately, but low- and high-hazard waste and low- and high-risk management

practices **may not** receive appropriate control. High-hazard waste may be underregulated, and low-hazard waste may be overregulated.

The current RCRA program provides one set of regulations and standards, with limited recognition that specific wastes and facilities may require deviations that can be accommodated at the permitting stage. There are some indications that the risk/cost model may be used to "fine tune" the basic set of regulations for certain generic situations. Thus, this model might complement the variance procedures at the permitting level.

In chapter 5, a general risk management framework was discussed. The elements of this general framework include hazard evaluation for wastes and facilities, risk estimation, evaluation of tradeoffs, assessment of management options, and choosing an appropriate course of action. Drawing from that general outline, this discussion presents a suggested decisionmaking framework designed specifically to account for varying levels of hazard for waste in their management, through the use of both waste hazard and facility classes. The factors determining different facility classes (for existing or planned facilities) include the performance capabilities (actual or anticipated) of the facility with regard to controlling release of hazardous constituents, monitoring programs, management procedures, training programs, the hydrogeologic characteristics of the site, the physical routes of potential transport of releases, the proximity of potentially affected people or sensitive components of the environment, and locally available resources for emergency response.

As was shown in figure 2, the framework is dynamic. Continuing collection of information and accumulated experience in permit writing can lead to adjustments in hazard classification of facilities and wastes. However, once a permit is issued (for 10 years under RCRA) changes in the system would have little effect on the permit holder, unless the permit holder voluntarily requested and received review and relief. At the permit writing stage, information about actual wastes and facilities are used to confirm or deny the judgments by the facility operator or waste generator concerning the appropriate Federal facility class, and possibly the waste hazard classes. Experience at the permit writing stage produces information for making regulatory policy changes concerning waste and facility classes, for establishing data and research priorities, and for improving the Federal data base.

If the permit writing authority is provided with a **small** number of waste and facility hazard classes (with specific technical criteria for technology performance standards, monitoring programs, and site requirements), choices can be made concerning levels of risk. This facilitates a "coarse tuning" of the regulations within the limits imposed by having several waste and facility classes. **The regulatory "tuning" process consists of matching waste hazard classes to the facility class.** This contrasts to the current system with one primary set of standards from which the permit writer can, for some types of facilities (e.g., landfills), make many deviations and exceptions (analogous to selection on a continuous band of options). However, for other types of facilities (e.g., incinerators), the current system may offer very little flexibility.

The permit writer's primary decision depends on fitting the real situation into a small number of options for regulatory control. The permit applicant is required to supply data consistent with the parameters used to classify waste and with the criteria used to define the corresponding levels of regulatory control. It should not be inferred that the illustrated framework can guarantee good permit decisions. A poor choice among the limited options available with the hazard classification approach could prove to be as detrimental as poor decisions made in the current system by the permitting authority.

How Hazard Classification Differs From Other Approaches

There are four approaches to implementing the degree-of-hazard concept. The listing approach is the simplest but may be the least adequate. From available information, lists of wastes are prepared to represent degrees of hazard. Use of this approach by EPA and some States indicates there remain considerable uncertainties as to the exact criteria used to establish the lists, or to obtain delisting. This list approach does not expeditious and effectively dealing with wastes that have not yet been listed, or with those candidates for delisting. Lists are often too generic and do not recognize major differences among individual waste constituents. At the Federal level, lists have not been related to differences in regulations and standards. Moreover, listing alone does not integrate the effects of different technologies and site-specific factors into a comprehensive risk management framework.

EPA has moved toward the development and use of the risk/cost model as a means to introduce more quantitatively the degree-of-hazard concept. It appears that the deficiencies inherent in the listing approach have been recognized. Using cost, however, as a means to balance risks appears contrary to the intent of RCRA: the cost component of this approach is not required for implementing the degree-of-hazard concept. It is the use of risk assessment that differentiates levels of hazard for wastes and the contribution of technologies and site-specific factors that determine actual levels of risk for a facility. The substantial increase in the amount of data required for the risk assessment approach makes it somewhat unique. It is necessary to obtain information beyond an understanding of the basic characteristics of the waste and indications of adverse human health and environmental effects. In risk assessment, considerable data on actual human health and environmental effects are preferable, although other data, such as animal effects, may be used out of necessity. There must also be considerable information on those factors necessary to assess risks, which include, for example, specific information on the transport and fate of releases into the environment, and on the responses of particular components of the environment to the release dosage. Although this approach can be precise, it lacks predictive capabilities. New situations require extensive data and analysis.

EPA may introduce the use of the risk/cost model as an adjunct to the flexibility achieved through permit writing. Permit writing is another way to introduce the degree-of-hazard concept into the regulatory framework. The main objections to using permitting as a **primary** means to achieve variations in level of regulatory control are: 1) many permit writers nationwide can be making decisions that are inconsistent with others, leading to inequities among facility operators, varying levels of public protection, and possibly the formation of "pollution havens;" 2) permit writers may lack access to technical data or the technical skills necessary to make satisfactory decisions about whether requested deviations from the primary set of RCRA regulations adequately protect health and the environment; and 3) with many individual decisions being made concerning variations in regulatory control, it is difficult for the public and policymakers (including Congress) to evaluate whether statutory requirements of RCRA are being completely met.

Hazard classification approaches are in contrast to the complex risk approach, the simple listing approach, and the decentralized permitting approach. The basic aspects of hazard classification are: 1) data on waste are used to describe adverse effects of exposure to hazardous constituents; 2) it is possible to classify wastes by similar levels of hazard; 3) it is possible to classify facilities of different technologies to afford a certain level of hazard reduction with regard to waste handled, or a certain performance level for controlling releases of hazardous constituents; and 4) waste hazard classes are matched to facility classes to achieve appropriate regulatory control. Decisions must be made concerning what types of data and what specific values are to be used in establishing the different classes of wastes and facilities. This is not necessarily simple, nor are the boundaries (values of different parameters) that define different classes rigid. A new waste can be classified as long as there are data corresponding to the boundaries for the classes.

It is emphasized that all suggested uses of hazard classification assume that **only a very few classes would be required and are practical.** Usually high, medium, low, and no hazard classes are envisioned. To some extent, therefore, the classification approach is more "coarse tuning" than the "fine tuning" achieved through risk assessment. Compared to the variations possible with permitting decisions, the classification approach offers permit writers an opportunity to select from a small number of choices. For example, a permit writer could change the classification of a waste (and therefore the level of regulatory control required for the facility) because of the concentration of a hazardous substance in the waste, or because of technological and site-specific factors. A facility with some type of waste pretreatment might require a reduced performance standard to achieve acceptable levels of release. A facility may be in a location in which any release would be so dispersed prior to any exposure to a vulnerable receptor that a lower performance standard would be acceptable. With hazard classification it is possible to integrate technological and site-specific factors into the use of varying hazard levels of waste. Options, however, are limited by the number of hazard classes available, and by the corresponding regulatory requirements, such as performance standards, monitoring requirements, and criteria for acceptable sites.

Objectives of an Integrated Risk Management Approach

Any integrated approach directed toward the hazardous waste problem should address certain key issues. These include:

1. consideration of degrees of hazard and risk in relation to waste and management practices;
2. assessment of the potential to reduce either the amount or hazard level of hazardous waste through the use of appropriate technology;
3. development of effective designs for monitoring strategies at all types of facilities; and
4. a means for addressing severe public opposition to siting of new hazardous waste facilities by providing a technically sound basis for evaluating management proposals.

The framework illustrated in figure 2 would address these issues and provide an integrated approach for data collection, hazard and risk estimations, evaluation of tradeoffs among risk, costs, and benefits. The specifics of how the issues are addressed are discussed subsequently. The outcome then can be used in making decisions concerning:

1. criteria for permitting and monitoring,
2. regulatory and policy changes, and
3. data and research priorities.

This decisionmaking framework emphasizes the need to classify waste by degree of hazard and to integrate data for risk evaluation associated with specific management approaches.

This framework is a tool with which government officials could formulate effective appropriate regulations for the treatment and disposal of hazardous waste. **It is not a formal classification system for actual regulation of waste management.**[*] If implemented as the basis for decisions within a governmental agency, it could provide the scientific and technical bedrock for sound decisions about regulation of hazardous waste. It also could provide government agencies, either Federal or State, with a tool for addressing public opposition to siting and management approaches. The objectives of this framework are:

1. to provide a consistent decisionmaking framework for achieving the goals of protection of human health and the environment,
2. to provide a mechanism for establishing criteria and priorities for reaching this goal, and
3. to maximize flexibility for officials to develop appropriate regulations for the management of waste.

Hazard Classification Considerations

In considering the degree-of-hazard concept, three characteristics of wastes are important: the chemical and physical forms that affect its treatability, characteristics of constituents that determine the hazard potential itself, and the concentrations and chemical forms of the constituents. Classifying wastes according to these characteristics and the hazard levels that each pose to health or the environment is discussed in chapter 6.

Afterward, data would be analyzed to determine both immediate and protracted hazards. The immediate hazards can be determined by assessing characteristics of reactivity, chemical incompatibility, ignitability, and corrosiveness. Long-term hazards can be determined from the toxic qualities of a waste and its constituents and from those characteristics that influence its distribution and fate in the environment—e.g., solubility, volatility, persistence, and bioaccumulation.

Development of hazard classes from specific criteria will not be an easy task, but will not be impossible. An ideal system might have four classes: high, medium, low, and no hazard. The criteria for each could be based on toxicity, genetic impairment, chemical and physical factors contributing to persistence and bioaccumulation, safety factors, and concentrations. As discussed in chapter 5, models are available that incorporate these elements, and these could serve as a basis for further criteria development.

The study prepared for OTA (see the discussion of case study in ch. 5) concludes it is possible to distinguish among wastes even using the inadequate data base currently available. Although the waste selected in the study are considered by EPA as being equally hazardous, it was possible to further categorize them into four levels, using classification models developed by the States of Washington and Michigan. The first step in the risk management framework, i.e., estimating degrees of hazard for the RCRA universe of waste, can be achieved in a limited way now. With a concerted effort to develop the necessary hazard criteria and appropriate characteristics and effects data for waste and constituents, a better estimation of degree of hazard for waste will be possible.

The classification of wastes would provide options for permit writers that reduce the technical burdens on them by providing established technical criteria to choose among. Without classification, permit writers face a large task of determining what factors to consider and then determining what the factor values signify in terms of hazard and risk. Difficulties associated with interpreting varying data would not be a major problem in classification. Initially, certain judgments would be necessary concerning the class in which a waste should be assigned. However, as more data are collected and new information incorporated within the data base, classification could be revised as necessary. It should be emphasized that before any hazard classification would be used in the RCRA program, considerable data will have been obtained from several years of permit writing. Because the classifications will shift one set of regulations and standards to perhaps three sets, such changes would not necessarily cause more disruptions in the regulatory process than would the risk/cost policy model or other attempts to "tailor" regulations. It is conceivable that some of the main, existing standards would correspond to the medium-hazard class, in which the majority of regulated waste would exist. Moreover, current regulations eventually will be changed as new data are incorporated in the evaluation of risks and assessment of tradeoffs.

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[*] The design and selection of a hazard classification system would require considerable attention to specific factors used to assess a number of different types of hazards, and then the selection of several critical values for these factors in order to establish boundaries between hazard classes. This study has not attempted to design or select a specific classification system, but, as considered in chapter 5, there appears to be sufficient evidence to indicate that a workable classification system could be developed with existing information.

An advantage of a waste classification system is that all potentially hazardous wastes are evaluated and the system becomes inclusive, rather than exclusive. The current problem of fluctuating status with respect to RCRA definitions would be largely removed. All wastes would be considered but each would be recognized for its specific hazard level.

The Link Between Waste Hazard Classification and Risk Estimation

The chemical and physical characteristics of waste strongly influence the technologies to treat it. Important physical characteristics include its form: solution, a solid, or a sludge. Important chemical characteristics include its origin: organic or inorganic. Waste can be further characterized as acid or alkaline, concentrated or dilute. Each influence the combinations, sequences, and cost of treatment and disposal options. Because of their physical and chemical diversity, treatment and disposal alternatives are diverse. No single treatment or disposal process can be considered exclusively appropriate or technically correct.

Many technologies have application in the management of hazardous waste. Some are applicable to several physical and chemical forms of waste; others have more limited application (see ch. 4). Three general practices are treatment to reduce hazard levels, containment to isolate waste from humans and the environment, and dispersion to reduce concentrations.

In the second element of the hazard classification framework, degree of risk is identified for each of these three categories of management practices by the permit writer who uses the classifications, assesses the risks of facility design and operation, and analyzes the potential environmental fate and distribution of waste that may be released from the facility.

As discussed in chapters 6 and 7, current models are inadequate for determining real-world risks associated with particular waste and management options. The models used should be capable of incorporating information about facility design, include changes in operational parameters that affect the potential release of material from the facility, and include estimates of possible exposure to humans and ecosystems. If this effort relies on simple models and indicator factors that do not reflect the real situations, the result will have limited utility in the decisionmaking process. Most models now proposed by EPA are very limited in scope and do not reflect the behavior of waste in the environment nor the potential level of exposure to organisms. Thus, effort must be devoted to developing assessment models that are multilevel oriented—not an easy task.

A review of the scientific literature suggests that many usable models do exist. Some evaluate the potential distribution of constituents within a variety of ecosystems and have the capacity to incorporate real elements and actual compound data. Other models use design and operation data for a facility type to determine the effluent under various operating conditions. By combining these two types of models, estimates of expected risks for different facility types and even for different designs of one type of facility could be formulated.

As with estimates of degree of hazard and classification of waste, the incorporation of this type of risk analysis in a decisionmaking framework has certain advantages. Because regulations would not be a direct result of the analysis, temporary misinformation would not have critical effects on the actual management of hazardous waste. Rather, the outcome of this step of the framework would be put directly into the third step: evaluating tradeoffs between perceived risks, costs of changing facility design, costs of specific regulatory changes, and the benefits that could be expected. By maintaining an ongoing assessment effort, new information can be included into the decisionmaking process as it becomes available.

Regulatory Decisions and Tradeoffs

The third step of the process involves evaluation of all risks, costs, and benefits associated with each management option within a hazard classification. Relying on the results of hazard classification and risks estimation, tradeoffs among management options, risks, costs, and benefits of each can be used to decide whether a waste should be classified differently, or whether a facility compatible with certain waste hazard classes could accept waste from a higher hazard class (clearly there would be no regulatory problem in using a facility compatible with a high-hazard class for wastes from lower hazard classes).

It should be emphasized that current assessment models—e.g., risk-risk and cost-benefit—have serious limitations. These are discussed in chapter 5. As long as these limitations are recognized and included in the decisionmaking process, such tools can be used. In this particular case of tradeoffs in management options for hazardous waste, some of the limitations associated with assigning dollar values to lives saved may be eliminated by assessing only for the potential for release of hazardous constituents from a facility. Guidelines would have to be developed to assure that each tradeoff evaluation was accomplished in reasonably compatible and uniform ways so that the results could be compared. Although further development of tradeoff models is necessary, limited use of current models is possible and would help in reaching decisions about alternative options for management of hazardous wastes.

Application of the Risk Management Framework

Application of the framework requires that data about the potential hazards posed by wastes and constituents be evaluated with data about the risks associated with different facility classes. This evaluation is done by developing the technical basis for matching waste classes with corresponding facility classes. The objective is to obtain the appropriate levels of regulatory control for the waste classes. The technical basis for such correlations is the use of health and environmental effects to assess how certain levels of control over release for certain wastes provide **a consistent level of risk—across the different waste and facility classes.**

This classification framework recognizes that wastes vary in the level of hazard inherent in their makeup and that for any facility type there can be variations in design and operation parameters that result in different levels of potential risk. The outcome of this risk management framework would have multiple uses. A major goal of this framework is to streamline the regulatory process by establishing a link between hazard class and minimum Federal performance standards for all applicable technologies.

Developing Criteria for Permitting and Monitoring Processes.—As regulations are written currently, the Regional Administrator or State permitting authority has discretion for determining the suitability of any facility and monitoring effort. This discretion recognizes the site-specific nature of a facility. The risk management framework illustrated in this discussion provides a means to develop such criteria based on technical information rather than judgments by the permitting authority. For example, specific application of any management option can be restricted in two ways: lack of technical feasibility and permitting monitoring requirements. In the former, there are some applications that are constrained because the technology will not change the hazard level of the waste, contain it sufficiently, or disperse it in concentrations that are not harmful to health or the environment. The use of a waste classification approach does not remove the necessity for the permit writer to decide what the applicable technologies are. The classification merely provides the set of details for determining the appropriate facility class—the level of regulatory control (i.e., performance standards, monitoring requirements, etc.) as indicated by the facility class for a specific waste class. For example, some highly concentrated solutions of toxic, polycyclic aromatics cannot be degraded with naturally occurring micro-organisms; thus, landfarming of these types of waste is not appropriate. Use of improved biotechnology methods have resulted in development of certain micro-organisms that can degrade such waste under controlled treatment conditions. Even though standards for landfarming may exist, the facility operator and the permit writer must decide whether the technology is applicable to that **specific** waste. Presumably, suitable guidelines could be offered. Similarly, certain sludges cannot be burned adequately in some industrial boilers because of the limitations of the feed control mechanism and the lining of the combustion chamber, but these same wastes can be incinerated in a rotary kiln incinerator. Thus, within a technology category (e.g., biological degradation and thermal destruction) and facility class, the limitations for application of a specific treatment (e.g., landfarming, advanced biotechnology treatment, or industrial boilers and rotary kilns) can vary as a function of the chemical and physical form of the waste.

A central concept supporting facility classification is the use of variations in performance standards for different technologies. Currently the regulations rely heavily on this method, but do so in the absence of any analysis of the preferred types of standard for specific technologies. There are several ways to define a technology performance standard. The common objective is to exert control over the release of hazardous substances into the environment.

Debate over the appropriate method for setting technology standards and for establishing acceptable levels of release is not unique to RCRA. At least six different approaches have been considered for use in implementing other environmental acts. Several of these have been considered in the rulemaking process under RCRA. These approaches require specifying: 1) a numerical standard for allowable concentrations of some contaminant remaining after treatment (the point at which these numerical standards come into effect can vary, e.g., at the point of emission, or as an ambient standard for land, air, and water at points of potential use); 2) specifying a percentage reduction of the concentration of a contaminant remaining after treatment, relative to its original concentration; 3) a time period during which waste must be contained in the waste management area; 4) specifying facility design and operating standards; 5) a nonspecific health and environmental performance standard—e.g., human health and the environment shall not be adversely effected by the migration of contaminants; and 6) specifying a ratio of quantity of emissions released per unit of raw material used in an industrial process. This latter type of standard has not been considered by EPA for incorporation into RCRA regulations.

Although these six approaches are presented as wholly separate concepts, there are instances where the technicalities surrounding their implementation blur the distinctions. For example, current incinerator regulations under RCRA specify a 99.99 percent destruction and removal for specified organic constituents within the waste stream. During the process of specifying the organics, original concentration(s) and incinerability in the waste stream must be considered. This is necessary because destruction of 99.99 percent of a very low-initial concentration will result in emission concentrations in the stack gas that may be far below the limits of detection.

No single standard can address all the variables governing releases of waste contaminants to the environment because of the differences in the types of technologies used to treat or to contain the waste. Releases from treatment alternatives such as chemical conversion or thermal destruction are fairly immediate, and their duration is generally related to the duration of the process itself. Further, the qualities and amounts of the contaminants released can be adjusted somewhat through control of the treatment process. For containment alternatives, such as landfills, releases occur over a longer period of time. During operation, there can be releases to the air and to the subsurface when the final cover to reduce infiltration of rainwater is not in place. There can also be releases that occur long after the landfill has been closed—e.g., as a result of a breach in the lining material. Further, as the leachate recovery system is only required to operate during the commercial life of the facility, and since the effectiveness of landfill cover maintenance in preventing infiltration of water into the landfill throughout the 30-year post-closure period has not been determined, there may also be migration of leachate from the bottom of the cells as liquid pressure increases on the liner. The extent to which these releases can be minimized depends on the design of the landfill and its materials of construction.

Thus, landfills are an example of a technology whose performance can be improved by the specification of certain design, operating, and location standards. The idea of using classification to streamline the regulatory process is based on establishing a credible and accurate link between a waste class and a facility class that in turn is based on minimum performance standards for a variety of technologies. However, it should be recognized that the greater stringency required for higher hazard classes will make some technology options impractical or unattractive. For example **the use of landfills for high-hazard waste would be made difficult by the very stringent performance standards and monitoring requirements associated with that class.**

Specific data requirements required in permit applications for all facilities would be developed to include all aspects of the framework:

1. providing suitable data for a determination of the hazard class for waste to be treated at the facility,
2. indicating choice of appropriate treatment or disposal options and including all information relevant to design and operation,

3. identification of all potential releases of significantly hazardous waste constituents to the surrounding environment, and
4. providing adequate information with which predictions of potential significant contaminants can be made.

By incorporating these data into the risk management framework, the permitting authority can select the suitable class of performance standards, monitoring programs, and establish a reporting and inspection schedule to assist the responsible agency (Federal or State) in its enforcement efforts.

Establishing Data and Research Priorities.—One outcome is to use the results to identify those areas that require more data—e.g., additional data needed on the fate of constituents in a landfill. Thus, funds could be allocated toward gaining the needed information. Research priorities might be identified—e.g., the evaluation may identify a class of waste or type of facility that pose an unacceptable threat to health and the environment. The responsible agency, State or Federal, could then develop research efforts to determine new ways to deal with this particular class of waste, or they could develop incentives to encourage industry to identify improved management options—e.g., in the form of reducing the generation amount of this class of waste, in developing better treatment process, or in devising new uses for the waste.

Identifying Areas for Regulatory and Policy Change.—Specific regulatory restrictions are another way of limiting application of a specific technology. In the environmental area, these restrictions are usually the result of a policy decision which evaluates the environmental effects of the use of that option. For example, regulations promulgated under the Marine Protection, Research, and Sanctuaries Act restricts the dumping of radiological and chemical warfare waste into the ocean because of the adverse effects they would have on the ocean, not because of any technical infeasibility of hauling and dumping such waste at sea.

The risk management framework provides a context within which areas that may need regulatory change can be identified using all available information. An assessment of whether to ban certain materials from landfills can be accomplished using this framework. A review of those wastes classified as highly hazardous and the available treatment technologies could result in a decision to ban them from land disposal because other suitable options do exist, rather than maintain the option of using landfills with the higher level of stringency required for this hazard class. In contrast, if there is a particular subclass of highly hazardous wastes that cannot be treated in any other way, than specific controls focused on those wastes can be required in the regulations for land disposal.

Policy changes can be similarly determined using the risk management framework. For example, the current EPA regulations include several wastes that are exempt from control. Some exemptions are statutorily mandated, others were granted by EPA. A review of the waste in low- or no-hazard classes and of the technologies that are used to treat or dispose of these wastes may indicate that controls in terms of performance standards or stringent monitoring requirements may not be needed. EPA may decide as a matter of policy that certain wastes must be tracked offsite through the manifest system and the final deposition (for waste managed onsite also) simply reported in both generator reports and facility management reports.

Data Collection.—The success of this framework lies with compilation of valid data about all aspects of waste management. **Without a well-developed data base, sound judgments at any step of the framework will not be possible.** The collection process must be continuous as improvement in the decisionmaking process will depend on new and better data. Data from all parts of the framework are fed into data collection efforts.

Addressing the Key Issues in Waste Management

The risk management framework presented here addresses the major issues in the current examination of the Federal RCRA program in the following ways:

1. the major focus is to estimate degree of hazard for wastes, classify them, and establish facility classes based on degree of risk (or control) associated with a specific technology and facility location;
2. the framework facilitates identification of waste that could be reduced and technologies that provide greatest reduction either in hazard level of the waste or in risk for exposure to health and the environment. Over time, policy changes can be considered to reduce the waste generated or to encourage development of technologies that reduce hazard and risks;
3. by correlating the hazard, waste, and the facility class, effective monitoring requirements can be formulated; and
4. a means for addressing public opposition to siting of new facilities by providing a sound basis for evaluating proposals is also incorpor-

ated in this framework. As discussed in chapter 5, public fears are motivated by a number of things: fear for health and safety, lack of confidence in governments and industry, and the absence of technically based siting criteria. If a decisionmaking framework is developed by Federal and State authorities, it would provide a signal to the public that governments are intent on establishing technically sound regulations, collecting data, establishing sound criteria for permitting and monitoring, and ensuring consistent environmental protection nationwide.

CHAPTER 4

Data for Hazardous Waste Management

Summary Findings

- Inadequate data conceal the scope and intensity of the national hazardous waste problem. Substantial improvements can be made in all data areas, and are particularly needed for health and environmental effects required for risk assessments.
- Although improved data are being obtained by the Environmental Protection Agency (EPA) and the States, effective implementation of government programs are hindered by major inadequacies and uncertainties concerning the amounts of hazardous waste being generated, the types and capacities of existing waste management facilities, the number of uncontrolled sites and their hazard levels, and the health and environmental effects of releases of hazardous waste constituents.
- Under State and Federal regulations some 255 million to 275 million metric tons (tonnes) of hazardous waste are generated annually, although the Federal program recognizes only about 40 million tonnes. States sometimes define hazardous waste differently than does the Federal program. This leads to differences in the perceived types and quantities of waste that pose hazards, and to confusion as to the degree and focus of efforts required to control hazardous waste. The Federal program exempts many millions of tonnes of waste deemed hazardous to varying degrees.
- The Resource Conservation and Recovery Act's (RCRA) permitting efforts for facilities will be based on the current EPA national data base. These data are generally recognized to be incomplete and, in some respects, inaccurate.
- The inventory of uncontrolled sites in the Nation is still incomplete, and the severity of the hazards posed by many of the listed priority and unlisted sites is uncertain.
- There are very limited data concerning the short- and long-term health and environmental effects of exposures to actual hazardous waste. The disease registry and the health survey mandated by the Comprehensive Environmental, Response, Compensation, and Liability Act of 1980 (CERCLA) have not been completed.
- There is a need for a long-term, systematic program in EPA—for which a congressional mandate does not exist—with the goal of obtaining more complete and reliable data on hazardous wastes, facilities, sites, and exposures to and effects from releases.

Introduction

"Hazardous waste management" is defined in the RCRA leglislation as (1):

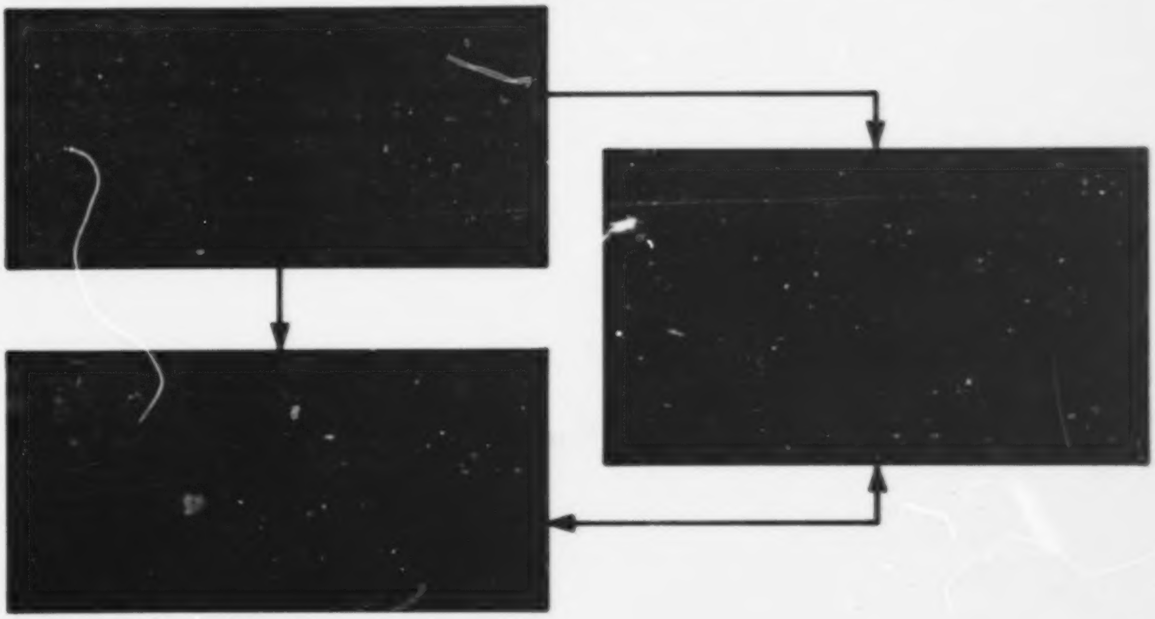
> . . . the systematic control of the collection, source separation, storage, transportation, processing, treatment, recovery and disposal of hazardous wastes.

Considerable data are required to determine the technologies and strategies suitable for managing a given hazardous waste. The roles of government, industry, and the public in the protection of health and the environment through hazardous waste management are complementary; however, the data needs of each group differ. It is necessary for government to define siting criteria, to regulate the design or performance of management facilities, to monitor compliance with these regulations, and to enforce the regulations. Industries must identify the nature and hazard of their waste, select existing technologies (or develop new ones) for effective management, and ensure adequate management of their waste. To assist government and industry in maximizing the effectiveness of hazardous waste management efforts, the public should have access to as much information as possible concerning the activities of hazardous waste generators and management facilities (with appropriate consideration of the proprietary nature of some information), and concerning regulations governing these activities.

To provide a framework for discussing these various data needs, the basic issues and information involved in managing a given hazardous waste stream are illustrated in figure 4. Figure 5 illustrates the possible paths that hazardous waste may take during the management process. Both of these models are deliberately simplified; they are intended only to present conceptual frameworks. The various chapters of this study address the components of these figures in detail.

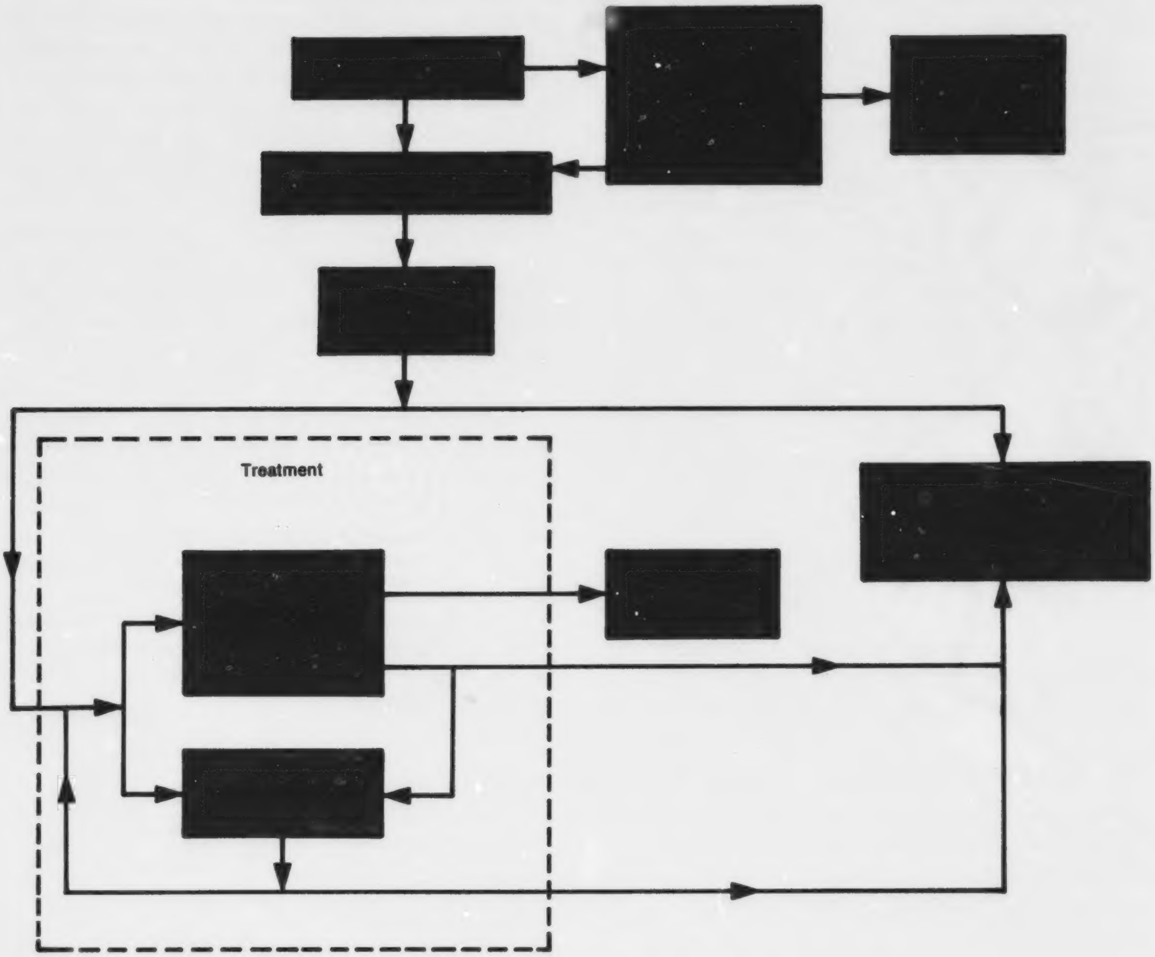
This chapter discusses the need and availability of data for hazardous waste management. First, the roles of government, industry, and the public are described, and a brief overview of relevant statutes and regulations is given. Second, data types discussed are described. Third, the universe of regulated waste is defined. Fourth, current data requirements, resources, and uses are discussed as they relate to generators and generation, health and environmental effects, and management facilities. Finally, some priorities are suggested for development of required data resources for effective hazardous waste management.

Figure 4.—Determination of Hazardous Waste Management Solutions



SOURCE: Office of Technology Assessment.

Figure 5.—Hazardous Waste Management Paths



SOURCE: Office of Technology Assessment.

Management Roles of Government, Industry, and the Public

Congress enacted RCRA in 1976 to address issues concerning current and future management of hazardous waste and the recovery of energy and materials. RCRA is but one of several Federal statutes concerned with public health and environmental quality through the management of hazardous substances. The relationship of these statutes to RCRA is more fully discussed in chapter 7. As a result of several environmental acts, sources of data have been developed concerning the chemical characteristics and potential impacts of hazardous substances on health and the environment. Information and expertise developed under each of these sometimes overlapping environmental statutes can contribute to the implementation of RCRA.

The **role of the Federal Government** as set forth in RCRA includes the establishment of a system that will protect health and environmental quality through proper management of hazardous waste. The responsibilities for implementing hazardous waste management programs are shared by the Federal government and the States. States have the authority to implement programs more stringent than required by the Federal program. RCRA focuses on hazardous waste management and transportation. The regulation of generators is limited to waste analysis and recordkeeping. EPA has promulgated a regulatory program designed to document and constrain the disposition of hazardous waste from point of generation to final disposal (see fig. 5). Table 15 summarizes RCRA and CERCLA mandates for data collection. Many of the required studies and surveys have not yet been completed.

The **role of industry** in the implementation of RCRA is an important one. Hazardous waste generators, as well as industries involved in hazardous waste storage, recovery, treatment, disposal, and transportation are involved. Industry's role in RCRA implementation is to comply with Federal and State waste management regulations, choosing waste management options that do not threaten health or the environment and balance both immediate costs and long-term financial liabilities. This choice should be based on adequate data resources.

Generators are required to maintain records of waste, reflecting the quantity and nature of the waste generated, and its disposition. Generators who transport their waste to offsite storage, treatment, disposal, or recovery facilities must maintain transport manifests.

The primary **role of the public** has been in creating a sense of urgency that motivates government to enact and implement hazardous waste management laws. Public participation is an essential ingredient in the development of the States' hazardous waste management programs. The public has another important function—that of visual monitoring and of reporting conditions in and surrounding hazardous waste facilities that may present a threat to health and safety.

Table 15.—RCRA and CERCLA Data Collection Mandates

RCRA data collection	CERCLA data collection
Subtitle C • Notifications by TSD[a] facilities[b,c] • Manifests of transported wastes[b,c,d] • Site inventory[d] Subtitle D • Inventory of open dumps[b] Subtitle E • Available recovery/recycling technologies[b] • Available energy/materials for reuse and conservation[b] Subtitle H • Special research and development projects[b] —waste characteristics —effects on health and the environment —waste management technologies	• List of at least 400 priority sites[b] • Inventory of published health effects[b] • National registeries[b] —Diseases and illnesses related to exposure to toxics —Persons exposed to toxics • Special studies[b] —Waste disposal sites —Screening programs and surveys on health and environmental effects • List of areas closed to the public due to presence of toxics[b]

[a] Treatment, storage, and disposal.
[b] Federal responsibility.
[c] Industry responsibility.
[d] State responsibility.

SOURCE: Office of Technology Assessment.

Types of Data

In this chapter, the term **data** refers to both numerical and nonnumerical information. Six data classes, are presented below:

1. **Type E:** Environmental data characterize the nature of the environment that is exposed to the waste. The data incorporate biological, ecological, geological, meteorological, and chemical characteristics, as well as all relevant transport mechanisms.
2. **Type W:** Waste data characterize a given waste. It is desirable that these data pertain to individual waste constituents and to the waste as a whole. Two types of waste characteristics are recognized:
   a. physical and chemical characteristics: state (solid, liquid, gas, solution or suspension in a liquid such as water), viscosity, density, flashpoint, corrosiveness, organic or inorganic, elements, compounds, mixtures, concentrations, chemical degradability, reactivity in ambient environments, reactivity in waste stream; and
   b. biological characteristics: toxicity (including genetic effects), nature of hazard, hazard level, persistence, degradability, tendency toward bioaccumulation, fate in humans and the environment.
3. **Type F:** Facility data characterize a single facility involved in the generation, storage, recovery, treatment, or disposal of hazardous waste. These data include location, operating characteristics, input-output waste characteristics, and the nature of environmental and human exposure to hazardous constituents associated with the facility.
4. **Type T:** Technology data characterize the typical performance of available management technologies (e.g., landfills, injection wells, incinerators).
5. **Type S:** State data represent the overall activity of all facilities in the State.
6. **Type N:** National data represent the overall activity of all facilities in the Nation.

Throughout the following discussion, the data type referred to is indicated by E, W, F, T, S, or N, where the type is not otherwise identified. The data needs of government, industry, and the public are summarized in table 16.

Table 16.—Summary of Data Needs

User	Legislation/regulation	Permitting	Monitoring	Enforcement	Planning	Public information
Federal Government	E,W,T	E,F	E,F	F	E,W,F,T	E,W,F,T
State government	E,W,T	E,F	E,F	F	E,W,F,T	E,W,F,T
Generators	W,T[a]				W,F,T	W,T
Management facilities	E,F,T	E,F	E,F	F	E,W,F,T,S	F,S
Public	E,W,T	E,F	E,F	F		

KEY: E—environment data; F—facility data; N—national facilities data; S—State facilities data; T—technology data; W—waste data.

[a] Data required to participate in the legislative and regulatory processes.

SOURCE: Office of Technology Assessment.

The Universe of Regulated Waste

The defined universe of hazardous waste varies among the States and the Federal program. RCRA defines hazardous waste as a subset of solid waste as follows:

> The term "solid waste" means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material,

> including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved material in domestic sewage or solid or dissolved materials in irrigation return flows, or industrial discharges which are point sources subject to permits under section 402 of the Federal Water Pollution Control Act, as amended . . . or source, special nuclear, or by-product material as defined by the Atomic Energy Act of 1954, as amended . . . (2)
>
> The term "hazardous waste" means a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may—
>
> (A) cause, or significantly contribute to an increase in mortality, or an increase in serious irreversible, or incapacitating reversible, illness; or
>
> (B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed (3).

RCRA requires EPA "to develop and promulgate criteria for identifying the characteristics of hazardous waste and for listing hazardous wastes . . . taking into account toxicity, persistence, and degradability in nature, potential for accumulation in tissue, and related factors such as flammability, corrosiveness and other hazardous characteristics" (4).

Chapter 7 describes the EPA process for identifying and listing hazardous waste. In 1978, EPA proposed a definition of hazardous waste which varied somewhat from the RCRA definition and modified that definition in 1980. The EPA definition is discussed in chapter 7.

RCRA excludes certain waste from regulation as hazardous; in some cases these exempted wastes are regulated under other environmental acts. For administrative ease in initiating the RCRA regulations, EPA set certain additional exemptions. Examples of RCRA and EPA exemptions are shown in table 17. Some of these exempted wastes pose relatively low hazards, but others are generally understood to pose serious threats. Several hundred million tonnes of wastes are likely now exempted annually, pose significant hazards. Such deregulation activities by EPA are substantial. Some typical examples are: the delisting of spent pickle liquor that is reused or accumulated, and transported for the purpose of reuse, or that is reused in wastewater treatment in a facility holding a National Pollutant Discharge Elimination System (NPDES) permit; regulatory deferral of waste from paint manufacturing and paint waste from the mechanical and electric products industry; and deregulation of stabilized residues where approved technologies are applied.

Some States have elected to broaden the RCRA and EPA definitions of hazardous waste to include various additional chemical compounds, waste produced by small-volume generators, waste specifically excluded by RCRA from regulation as hazardous in the Federal program, various solid wastes, or waste specifically excluded by RCRA from regulation as solid waste.

Data Requirements: Generators and Generation of Waste

Federal and State Governments require waste generation data for legislation, regulation, and public information. The **development of legislation** requires information concerning the amounts and types of waste generated, feasible regulatory strategies, and costs of regulatory options. For purposes of **regulation**, and for **public information**, the universe of hazardous waste requiring management should be defined and generators of such waste must be identified. Methods of waste management, and the amount being generated in each locality, should be determined. Potential health and environmental effects should be identified.

Table 17.—Examples of Exemptions From Federal Regulation as Hazardous Waste

Waste type	Estimated annual generation (million metric tons)	Possible hazard	Determined by
Fly and bottom ash from burning fossil fuels[a]	66	Trace toxic metals	RCRA
Fuels gas emission control waste	Unknown	Toxic organics, and inorganics	RCRA
Mining waste, including radioactive waste[b]	2,100	Toxic metals; acidity; radioactivity	RCRA
Domestic sewage discharged into publicly owned treatment works[b]	5	Uncertain, toxic metals likely	RCRA
Cement kiln dust[a]	12	Alkalinity, toxic metals	RCRA
Gas and oil drilling muds and production waste; geothermal energy waste	Unknown	Alkalinity, toxic metals, toxic organics, salinity	RCRA
NPDES permitted industrial discharge	Unknown	Toxic organics, heavy metals	RCRA
Irrigation return flows	Unknown	Pesticides, fertilizers	RCRA
Waste burned as fuels[c]	19	Unburned toxic organics	EPA
Waste oil	Unknown	Toxic organics, toxic metals	EPA
Infectious waste	Unknown	Infectious materials	EPA
Small volume generators[d]	2.7-4.0	Possibly any hazardous waste	EPA
Agricultural waste	Unknown	Variable	EPA
Wastes exempted under delisting petitions	Unknown	Presumably insignificant†	EPA
Deferred regulations	Unknown	Unknown	EPA
EPA deregulation	Unknown	Presumably insignificant	EPA
Toxicity test exemptions‡	Unknown	Organics	EPA
Recycled waste‡	Unknown	Improper application of various materials	EPA

†Wastes may be delisted on the basis of a petition that is concerned only with the constituent(s) which have determined the original listing; however, other hazardous constituents may be present which have previously been unrecognized administratively.

‡Wastes not identified as toxic by the EPA extraction procedure test and not otherwise listed by EPA.

‡Legitimate recycling is exempt from RCRA regulations except for storage. However, there have been numerous incidents (e.g., the dioxin case in Missouri) involving recycled materials which are still hazardous.

SOURCES: [a]*Federal Register*, vol. 43, No. 243, 12/18/78.

[b]"Technical Environmental Impact of Various Approaches for Regulating Small Volume Hazardous Waste Generators" (Washington, D.C.: Environmental Protection Agency, contract No. 68-02-2613, TRW, December 1979).

[c]"A Technical Overview of the Concept of Disposing of Hazardous Wastes in Industrial Boilers" (Cincinnati, Ohio: Environmental Protection Agency, contract No. 68-03-2567, Acurex Corp., October 1981).

[d]"The RCRA Exemption for Small Volume Hazardous Waste Generators, Staff Memorandum" (Washington, D.C.: U.S. Congress, Office of Technology Assessment, July 1982.

As for industrial data needs, the generators of hazardous waste require facility data concerning specific waste quantities, constituents, and concentrations if they desire to modify their industrial processes to reduce the quantity and hazard of the waste they generate. The waste management industry requires the same information. And, for the purpose of market surveys, both the generation and management industries require data concerning management technologies appropriate and available to handle generated waste, the location of existing facilities, and the quantity and types of waste these can handle, in addition to their current utilization.

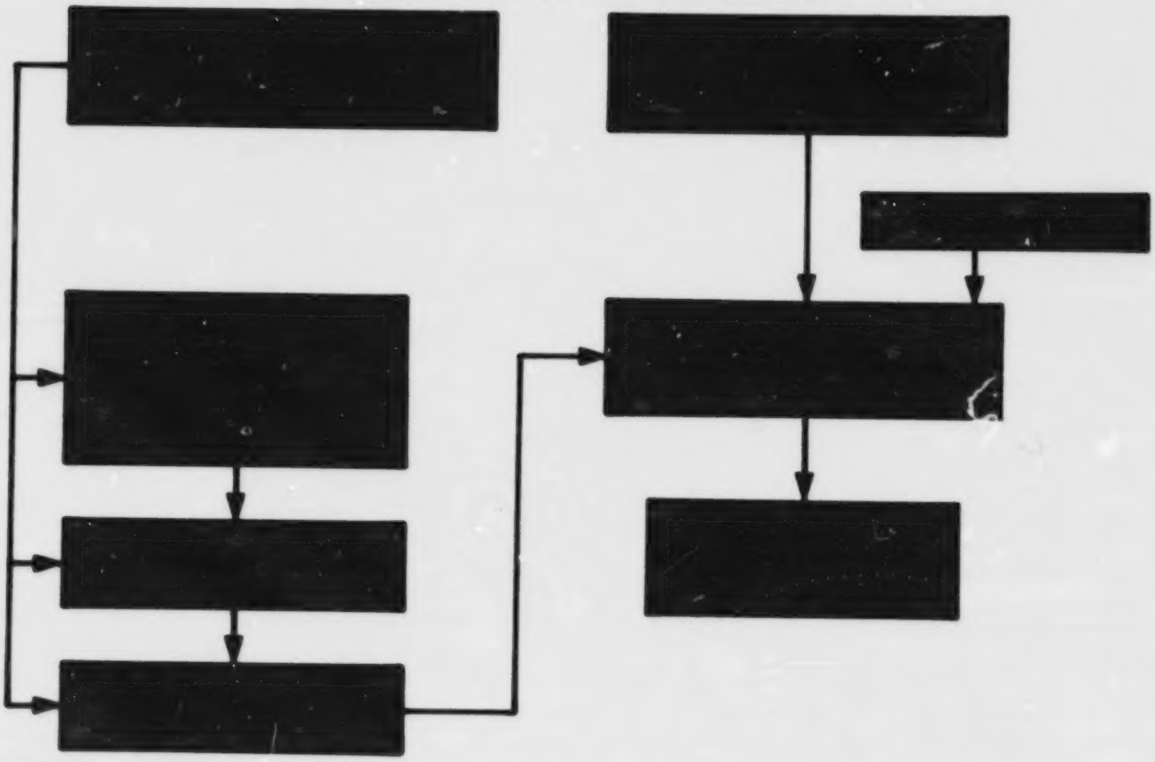
In order to maximize the effectiveness of the public in hazardous waste management, information concerning waste generators, waste generated, and health and environmental effects should be made broadly available.

National Data

Much of the existing data on hazardous waste generation have been developed in a series of studies completed between 1975 and 1982 (5-29). These studies and the relationships among them (the use of one study by another) are shown in figure 6. Also shown is a data set derived from the Federal regulatory requirement that all handlers of potentially hazardous waste notify EPA of their activities.

EPA contracted with several consulting firms during the early 1970's for analyses of waste generated by industrial sectors (mostly manufacturing industries) (5-19). Each contractor developed its own definition of the universe of hazardous waste. The methodology used in each study varied. In general, the contractors calculated aggregate hazardous waste amounts within broad industrial categories by using sev-

Figure 6.—Hazardous Waste Generation Data



SOURCE: Office of Technology Assessment.

eral methods. Some studies identified the scope of an industry (e.g., number of plants and location) by using direct industrial information, U.S. Department of Commerce data, or by visiting a small number of "typical" facilities (fewer than 10) and then using the waste generation data for those facilities and data on the number of employees to estimate hazardous waste generation nationwide.* Other contractors identified the numbers of plants nationwide, designed a theoretical model facility, and extrapolated national waste generation using the model. Certain assumptions concerning waste generation and management were applied in these studies. For example, it was assumed that the plants would be in compliance with waste discharge requirements under the Clean Water Act and other environmental legislation; such an assumption would produce a low estimate of total hazardous waste generation. It is unclear whether efforts were made to account for differences in waste generation that would result from variations in manufacturing processes, raw materials, and management practices among individual plants.

The 15 industry studies formed the data base for a number of separate efforts to estimate national hazardous waste generation. Among these are studies by JRB Associates (20), Battelle Columbus Laboratories (21), Development Planning and Research Associates (DPRA)

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*A recent study for Virginia indicated that the methodology using employment data can be in substantial disagreement with waste generation data obtained from surveys of generators. For example, liquid wastes were underestimated by about 30 percent, and waste sludges and solids were overestimated by close to 20 times. ("Survey of Hazardous Waste Generators in the Commonwealth of Virginia," Malcolm Pirnie, Inc., October 1982.)

(22-24), and Arthur D. Little (25). EPA also used data from the 15 industry studies in the 1978 draft RCRA Regulatory Impact Analysis (26, 27). Although the same basic data appears to have been used by all, there were variations in the national hazardous waste estimates produced by these efforts. These variations resulted primarily from differences in the statistical methods employed and the time periods represented in each study.

EPA also contracted with TRW (28) to provide an estimate of waste produced by small-volume waste generators. In the course of this effort, TRW provided a national estimate for hazardous waste generation of 61 million tonnes per year. Information concerning the methods of data collection and the analytical techniques used in this study is incomplete. The TRW estimate of 61 million tonnes appears to be derived from data provided by States, industry, and other unspecified EPA consultant reports. The study involved estimation of waste generation rates from data attributed to individual plants of various sizes, and the application of these rates to the distribution of plants reported by the U.S. Bureau of Census. The TRW definition of hazardous waste included, in addition to wastes covered by the EPA definition proposed in 1978, other wastes having certain constituents which were believed by the contractors to be hazardous in pure chemical forms. How much this latter group broadened the universe of hazardous waste as compared to the original 15 industry studies remains unclear. TRW included small-volume generators in its national estimate of hazardous waste. The contributions of small generators to the estimates in the 15 industry studies is not known.

In 1979, EPA contracted with Putnam, Bartlett and Hays (who subcontracted with Booz Allen and Hamilton) to summarize existing hazardous waste generation data and to undertake a survey of commercial hazardous waste management facilities. The purpose of the study (29) was to determine if sufficient management capacity existed to handle the total hazardous waste for 27 priority manufacturing and nonmanufacturing industry sectors (identified by "standard industrial classes," known as SICs). Booz Allen and Hamilton used the data base from the earlier industry studies. Consequently, all variations and limitations in definitions and methodologies from these studies were incorporated in the Booz Allen and Hamilton study. In addition, the data did not correspond to consistent time frames, or to whole industry sectors. To correct for these discrepancies, three general types of statistical adjustments were made:

1. Estimates were adjusted upward to account for the growth of waste generation since the date represented by the source data. (This adjustment does not reflect the recent downturn in industrial activity.)
2. Estimates were adjusted upward to account for waste generation in at least some industries not included in the original study.
3. When estimates referred to only part of an industry sector, the generation rate for the total sector was developed by calculating the ratio of production worker hours to waste generation in the subsector, and applying that ratio to the total industry.

The national quantity of hazardous waste generated annually was estimated by this study to be in the range 28 million to 54 million wet tonnes for the year 1980. EPA commonly reports a figure of 41 million wet tonnes for 1980 and 43 million wet tonnes for 1981. It is acknowledged that these figures do not include data concerning waste not regulated by RCRA.

In 1980, EPA required hazardous waste generators, owners and operators of hazardous waste treatment, storage, and disposal facilities (TSDF), and hazardous waste transporters to notify EPA of their activities. Information submitted included identification of facility type (i.e., generator, TSDF, transporter), location of the activity, and the types of waste handled according to EPA-established identification numbers. Notices were sent to 428,522 firms that had been identified by WAPORA (a consulting firm) as possibly being subject to RCRA regulation. EPA received approximately 60,000 notifications.

Also in 1980, EPA established a requirement for annual reporting of waste generated and received. This reporting requirement, effective that year, extended only to generators and waste management facilities in States with unauthorized State programs. (At that time, no States had authorized waste management programs.) In 1981, the Federal annual reporting requirement was suspended, and only a few States had partially authorized waste management programs. In October 1982, when the reporting requirement was reinstated retroactive to 1981, all but 16 States had achieved partial State program authorization. Since EPA still only requires generators and waste management facilities in States with unauthorized programs to report annually to EPA, the data received by EPA will represent activities in only a small number of States. EPA has also proposed a regulatory change to undertake biennial statistical samples from all the States in lieu of more comprehensive annual reporting requirements. Finally, EPA has undertaken a new national survey of hazardous waste generators and management facilities. This survey of approximately 10,700 generators and 2,500 management facilities is scheduled to be completed in 1983 and it will provide background information for the ongoing RCRA Regulatory Impact Analysis.

State Data

A number of States have attempted to estimate hazardous waste generation in their jurisdictions. These estimates were based on:

1. State inventories of waste generation by facility (including transport manifest data, State facility inventories, and data from generator notifications to the States);
2. extrapolations of the Booz Allen and Hamilton data using EPA notifications for a particular State;
3. data from State manifests for waste transported offsite.
4. extrapolations of State-derived estimates using methodologies similar to the national studies (20-29).

In addition, to address the need for new hazardous waste management facilities and to provide sources of information to the public, some States have formed regional planning organizations. These regional organizations have published estimates of regional waste generation (30-33) using State-supplied estimates of waste generation, or, in recent publications, by extrapolating regional waste generation from member States' manifest data. State waste generation data are discussed below. Chapter 6 discusses hazardous waste management facility siting.

The Association of State and Territorial Solid Waste Management Officials (ASTSWMO) surveyed State data for OTA (33). The results of that survey are presented in table 18. As part of this work, ASTSWMO requested the States to indicate broad differences between the State and EPA universes of hazardous waste. The States were also requested to indicate how their estimates were derived. The ASTSWMO information was obtained both by telephone and written response to a survey questionnaire. Forty-two States and five territories responded, but the completeness of their responses varied. As table 18 shows, the ASTSWMO study indicates approximately 250 million tonnes of hazardous waste are being produced annually by 40 States, Guam, and Puerto Rico.[*] The waste from the States and territories not responding might add another 5 million to 25 million tonnes annually to this figure (for a total likely range of 255 million to 275 million tonnes).

The States' waste generation data were derived by a number of different approaches: 19 States appear to have used State inventories; 5 States appear to have used data on manifested hazardous waste, thus underestimating waste generation unless extrapolation to account for waste managed onsite was done. In

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[*] Hazardous waste quantities reported in units of volume (gallons, cubic feet, cubic yards) were converted to units of weight by ASTSWMO using standard EPA conversion factors, as noted in table 18. However, in those cases where States reported quantities in units of weight, the factors used by the States for original converting volume to reported weight (where this conversion was performed) are unknown to OTA.

Table 18.—Hazardous Waste Generation Estimates by EPA and the States

State[a b]	Quantity (tonnes)		Universe	
	EPA estimate	State estimate	Same as EPA	State additions[c]
Alabama[b]	730,000	265,680		PCBs.
Alaska[b]	130,000	360		PCBs.
Arizona[b]	160,000	4,280,000		PCBs, waste oil.
Arkansas	370,000	No data[d]		PCBs, waste oil.
California[a]	2,630,000	15,000,000		Approximately 4 mmt is oilfield waste; also includes mining waste, small generators, PCBs.
Colorado[b]	180,000	775,490		PCBs.
Connecticut[b]	610,000	102,000	x	Extrapolated from 3 months manifest data.
Delaware[a]	300,000	272,000	x	—
Florida	960,000	No data	x	—
Georgia[b]	700,000	38,500,800		Some delisted waste; 99.7% is high volume, aqueous solutions, neutralized on site and discharged to sewers and receiving waters.
Hawaii	30,000	No response		—
Illinois[a]	2,530,000	1,810,000		Manifest data only.
Indiana	1,280,000	94,900,000		Includes 92.3 mmt of steel industry wastes, pending delisting and currently regulated under NPDES permit.
Idaho	80,000	No response		—
Iowa	300,000	No response		—
Kansas[a]	350,000	45,300		Refinery waste, small volume generators.
Kentucky[a]	700,000	415,000	x	—
Louisiana[a]	1,250,000	38,800,000		Fly and bottom ash, small volume generators, substances with LD_{50}.
Maine[b]	130,000	5,290		Mineral spirits, tanning industry waste, small volume generators, infectious waste.
Maryland[a]	590,000	272,100		Waste oil, PCBs, fly ash, and other unspecified waste.
Massachusetts[b]	820,000	172,000		Waste oil.
Michigan[b]	1,990,000	408,000		Extrapolated from manifest data; 280 compounds (including waste oil) not on EPA list.
Minnesota[b]	360,000	181,000		PCBs, crank case oil.
Mississippi[a]	340,000	1,810,000	x	—
Missouri[a]	910,000	658,930		Waste oil.
Montana[a]	50,000	91,200	x	—
Nebraska[b]	120,000	0.5% of national total)		Special waste including infectious waste.
Nevada	50,000	No response		—
New Hampshire[a]	100,000	9,980		Imported PCBs, waste oil.
New Jersey[a]	3,120,000	855,000		Manifest data only; waste oil, PCBs, some delisted waste, and other unspecified compounds.
New Mexico	60,000	No data		Small volume generators, PCBs, waste oil.
New York[b]	2,320,000	1,270,000		PCBs.
North Carolina	1,330,000	No response		—
North Dakota[a]	30,000	125,000	x	—
Ohio[a]	2,570,000	3,280,000		Solid waste on a case-by-case basis.
Oklahoma[b]	230,000	3,570,000		PCBs.
Oregon[b]	200,000	19,100		PCBs and other unspecified compounds.
Pennsylvania[b]	2,550,000	3,628,000		Other unspecified compounds.
Rhode Island[a]	190,000	1,600		A generally broader definition which includes waste oil, low-level radioactive.
South Carolina[b]	1,140,000	1,587,000		Waste oil, paint waste, unstabilized sewerage sludge.
South Dakota[b]	10,000	1,590		Waste oil.
Tennessee[a]	1,820,000	4,300,000	x	—
Texas[a]	3,010,000	29,146,980		Generally different definition which includes sludge, fly and bottom ash, water soluble oils, boiler sludges, PCBs, and other solid waste.

Table 18.—Hazardous Waste Generation Estimates by EPA and the States—Continued

State[a b]	Quantity (metric tons)		Universe	
	EPA estimate	State estimate	Same as EPA	State additions[c]
Utah[a]	110,000	558,000	x	—
Vermont[b]	30,000	9,070		Waste oils, infectious waste, PCBs, industrial laundries, some waste delisted by EPA, and other unspecified compounds.
Virginia[b]	1,220,000	181,000		PCBs.
Washington[b]	380,000	616,000		Additional unspecified waste.
West Virginia	790,000	No response		—
Wisconsin[a]	630,000	81,600		—
Wyoming	40,000	No response		—
Guam[b]	n/a	1,450	x	—
Puerto Rico[b]	560,000	417,000	x	—
North Mariana Island	n/a	No response		—
American Samoa	n/a	0		—
District of Columbia	140,000	No data	x	—
Virgin Islands	n/a	No response		—
Total	41,200,000 (excl. 2 terr.)	250,000,000 (excl. 10 states, 3 terr.)		

[a] State data based on inventory.
[b] State data based on consultant and/or State agency estimates.
[c] PCBs are currently regulated under TSCA. EPA is considering transferring regulation of this substance to RCRA jurisdiction.
[d] A few States did not supply information to this survey.
[e] The State figure of 15 million tonnes is from the testimony of S. Kent Stoddard, Office of Appropriate Technology, House Subcommittee on Natural Resources, Agriculture Research and the Environment, Dec. 8, 1982; it is based on a recent State study.

Conversions:
gallons × 0.00378 = metric tons
tons × 0.907 = metric tons
cubic feet × 0.02828 = metric tons
cubic yards × 0.76441 = metric tons

SOURCE: State estimates and associated information by ASTSWMO unless noted otherwise; EPA estimates by Office of Solid Waste for 1980.

the case of New Jersey, a recent study has indicated that in addition to the wastes reported in the survey results, as much as 3 million tonnes of hazardous wastes annually may be dumped into the ocean.* Data from the remaining responses were derived through use of EPA notifications and estimates of waste generated by industrial sectors represented by the notifications. Only 9 States, Guam, Puerto Rico, and the District of Columbia use definitions of hazardous waste that are reportedly the same as that used by EPA. Thirty-two States have adopted definitions that include RCRA-exempted waste (e.g., mining waste, waste from energy production, or waste resulting from the application of environmental controls) or EPA-exempted waste (such as PCBs, or those produced by small-volume generators).

Some States have included materials, including hazardous waste and contaminated soil, requiring management under RCRA which have resulted from cleanup actions at uncontrolled sites. Nationally, these cleanup efforts are just beginning. However, very large amounts of hazardous materials will be generated in the future as CERCLA activities increase. It appears that EPA estimates of hazardous waste generation do not include materials resulting from cleanup actions. Nonetheless, the magnitude of this source of "cleanup wastes" to be managed under RCRA is great. In the past, most hazardous wastes have been land disposed (as much as 80 percent) and, according to EPA estimates, 90 percent of these were probably mismanaged. Therefore, several hundred million tonnes of wastes themselves, plus large amounts of contaminated materials (e.g., soil) resulting from leakage, may require management in the future. Estimates for California are that about 100,000 tonnes of hazardous materials will be produced annually from cleanup actions during the next 10 years. Extrapolating to the national level, it is likely that several million tonnes of "cleanup wastes" may be produced annually during the coming decade.

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*This figure for ocean dumping was based on data from EPA permits for five waste generators; other data for 1978 indicated a total of about 2.5 million tonnes. It is quite possible that current tonnages may be less; however, the wastes may still be generated in New Jersey. (Environmental Resources Management, Inc., "Hazardous Waste Management Facility Study for the Delaware River Basin and New Jersey," May, 1982.)

In table 18, five States (California, Georgia, Indiana, Louisiana, and Texas) reported very large volumes of waste which they define as hazardous, totaling about 85 percent of the 250 million tonnes reported. These States define hazardous waste differently from either the EPA universe or other respondents in the survey. For instance, 99.7 percent of the waste reported by Georgia represents dilute aqueous solutions, which are neutralized onsite prior to discharge to sewers and receiving waters, but which, nonetheless, are hazardous waste. In Louisiana, the estimate includes waste from energy production, waste from environmental control activities, and fly and bottom ash. In Texas, the estimate includes large-volume waste from energy production, fly and bottom ash, environmental control activities, mining waste, and waste from the demolition of old highways, bridges, and buildings. Indiana's total of 94.9 million tonnes includes 92.3 million tonnes of spent pickle liquor generated by the steel industry. A request by this industry for deregulation under RCRA has been made to EPA.

Several other points should be noted about the figures in table 18. Many of the federally exempted wastes indicated in table 17 are not now regulated by a significant number of States. Many States have recently conducted, or are now conducting, studies on waste generation to obtain more accurate data on waste generation than previously available from EPA. Moreover, much of the data obtained from the ASTSWMO survey and the data becoming available from individual State studies, cover waste generation within the past 2 years (1981 to 1982). This period is one of a depressed economy and lower levels of industrial operation as compared to the pre-1980 period from which the EPA waste generation data were obtained. On the other hand, there is considerably more effective reporting of waste generation figures now than in earlier years, tending to increase recent estimates relative to older ones. Because of the lack of consistent data from the ASTSWMO survey on amounts of waste generated (corresponding to the federally defined sphere of regulated waste v. State-defined waste) and because of the effect of national economic cycles, direct comparisons with EPA data for the States, also given in table 18 are not completely appropriate.

In addition to the information about waste generation, ASTSWMO asked the States for information about the number of hazardous waste generators in their jurisdictions. Forty-three States and four territories reported approximately 55,000 hazardous waste generators, including in some instances an unspecified number of generators exempted under the EPA program. This figure is substantially lower, and the distribution among States may be substantially different, than the figure of 428,522 currently used by EPA in its formula for allocation of funds to the States. However, the figure of 55,000 generators is in agreement with the 60,000 notification responses which were received by EPA in 1980 (as previously discussed), and with the less than 8,000 waste management facilities verified for 1981 (discussed below).

The foregoing existing data correspond to items discussed under Federal and State Government data needs in the previous section. These data may also be of use in formulating strategies and regulations for hazardous waste. Industry's need for data concerning generators and generation does not appear to be substantial. The public's data needs concerning generators and generation will be met progressively as data collected by Federal and State authorities become more reliable.

Uses of Existing Data

The previous discussion of existing data identified various studies that have attempted to quantify both the number of waste generators throughout the Nation and the amount of waste produced annually. These studies have often lacked adequate definitions of hazardous waste, and there have been variations in definitions among the studies. Also, indirect methods of waste measurement were used in these studies, and direct generation data were sometimes lacking. These problems have led to a discrepancy between the actual quantity of hazardous waste generated annually in the Nation and the quantity perceived in any one study. There are variations among the various studies in perceived quantities of hazardous waste generated.

The reason for seeking waste generation data is to determine means for managing (storing, recovering, treating, transporting, and disposing of) actual—as opposed to perceived—generated waste, in a manner commensurate with the protection of health and the environment. Therefore, the following questions must be addressed:

1. Are the existing generation data useful for the task of actual hazardous waste management?
2. How are these data currently being used for this task?
3. What are the limitations of these data for this task?

Existing National and State generation data represent at best a limited characterization of actual generated waste. These data indicate to some extent the type of waste being generated, relative quantities, and fractional distribution by State. The data cannot be used as a measure of actual waste (by type or in total) being generated in any one State or in the Nation, except to infer that a large quantity of hazardous waste is in fact being produced annually, and that this waste must be managed quickly and effectively.

EPA has found only one administrative use for the existing generation data—in the allocation of Federal funds to State waste management programs, as described below. Faced with the uncertainties implicit in the generation data, and with the need to begin a hazardous waste management program, EPA made two strategic decisions. It was decided that the most pressing problem was industrial hazardous waste from certain priority industries, and that these wastes were adequately characterized with regard to waste type and distribution (for preliminary purposes) by the industry reports (5-19) and the derivative study by Booz Allen and Hamilton (29). Furthermore, the decision was made to allocate Federal funds to States using a formula whereby 40 percent of the amount for a State was determined by its fraction of the national waste stream (28.7 million tonnes), 40 percent by its fraction of the Nation's population, 15 percent by its fraction of the Nation's hazardous waste generators (428,522 was used even though only 60,000 responses were received by EPA from those receiving notification forms), and 5 percent by its fraction of the Nation's land area.

It is EPA's intention to progressively modify the values used in the fund allocation formula (and perhaps the formula itself) to reflect improved waste generation and population data, and changing definitions of hazardous waste, for fiscal year 1983 and beyond. The allocation formula was developed some 3 years before completion of the Booz Allen and Hamilton study and has been incorporated in EPA regulations up to the end of fiscal year 1982. It was "unanimously approved by more than 20 State representatives of the National Governors Association" (34). However, this was before there were indications that the data used by EPA might be seriously in error, as more recent State data suggest.

EPA's use of existing data for Federal fund allocation was probably necessary, given its need to act. EPA is certainly aware of the need to improve its generation/generator data base. Further, OTA has been unable to identify any additional administrative use for the existing data. However, as indicated earlier, public sense of hazardous waste problems provides an important influence on public, political, and regulatory activities. On the basis of the EPA estimates for hazardous waste generation and past practices, information concerning the national problem can be communicated to the public. For example, the accumulation of hazardous waste in the environment from past decades of industrial activity is currently equivalent to at least 1 tonne of hazardous waste for every person in the Nation and another tonne is added every 7 years, at current rates. These estimates may even be too low. If ASTSWMO waste generation data are more indicative of the national problem, then more than a tonne of hazardous waste may be placed into the environment every year for every person in the Nation.

Data Requirements: Health and Environmental Effects

For effective hazardous waste management, the effects of hazardous waste on health and the environment must be known to government, industry, and the public. Determination of the effects of a particular waste on a particular population can involve some very complex issues (see ch. 6 for a detailed discussion of hazards of waste and problems and data needs associated with determining hazard levels). In order to address the effects of waste comprehensively, data are required concerning:

1. the characteristics of waste: constituents, chemical, and physical data;
2. environmental characteristics: pathways, physical characteristics of the environment (air, water, soil), and distribution and characteristics of the population;
3. toxicological data: dose response and exposure factors; and
4. environmental fate and distribution: persistence, bioaccumulation, and media distribution.

Existing Data

It is generally understood that the number of chemical compounds currently recognized in the United States exceeds 3 million and approximately 3,000 new ones are being added each year. The physical and chemical characteristics of these substances can be obtained. There is a subset of these known chemicals for which health and environmental effects data have been collected, and about 500 chemicals are being tested under the Toxic Substances Control Act (TSCA) jurisdiction each year to broaden the scope of these data. In addition, TSCA requires industry to characterize all new chemicals, and chemicals for which they plan new uses, with respect to health and environmental effects that may occur through commercial use and disposal. It is not known whether the subset of chemicals for which detailed and reliable information is available represents a significant portion of all existing substances that pose a threat to health and the environment.

The known hazardous effects of the various chemicals can be classified into three groups:

1. physical harm—burns, or other effects due to exposure to acids, caustics and the like;
2. toxic effects—acute and chronic damage; and
3. genetic impairments—a variety of effects directed to genetic components of cells.

Much of the available data is derived from animal studies. The problems that result from extrapolating these data to humans are discussed in chapter 6. Information about chemical characteristics and known effects is reported in a variety of data bases illustrated in table 19. In principle, all of these data are available to the public, but few mechanisms are in place (within Federal and State programs) to facilitate public access or public understanding. The data are being developed by various groups including universities, the National Institute of Environmental Health Science, the National Institute of Health, the Centers for Disease Control (CDC), and the National Institute for Occupational Safety and Health. CDC maintains a large quantity of epidemiological data. As required by TSCA, industry supplies EPA with data on each new substance developed, including its chemical and physical properties, its health and environmental effects, and some limited information on waste management. All of these data are developed under statutes other than RCRA, and may not specifically address RCRA concerns.

Table 19.—Health and Environmental Effects Data

Source	Subject	Where maintained
MEDLINE	Recent articles on research; articles on diseases and chemicals.	National Library of Medicine
TOXLINE	Toxicological information from human and animal toxicology studies; the effects of chemical on the environment; adverse drug reactions; analytical methodologies.	National Library of Medicine
EPA-NIH Chemical Information System	Physical, chemical, and regulatory information about chemical substances.	National Institutes of Health
International Register of Potentially Toxic Chemicals	17 profiles on chemicals: essential physical and chemical properties; toxicity; reported effects on humans and laboratory organisms, and the environment; safe and effective use of chemicals.	UN Environment Program
Toxicology Data Bank	Literature on general toxicology which has been subjected to peer review.	Library of Medicine
Registry of Toxic Effects of Chemical Substances	Toxic effects of chemicals, including aquatic toxicity rating, cancer reviews.	NIOSH, CDC, Public Health Service
Chemical Activity Status Report	Lists chemicals research, authority for research, purpose, and information contact.	EPA

SOURCE: Office of Technology Assessment.

The threat that a hazardous substance poses to health and the environment can take many forms and vary significantly in degree (see discussion of hazard in ch. 6). Although a variety of tests are available to generate data concerning health effects, there has been little effort made to standardize protocols for interlaboratory comparisons of a single compound, or to standardize methodologies that facilitate comparisons among compounds for a variety of species.

Little data are available regarding the fate of any given waste constituent once it enters the environment. There are virtually no data concerning the interactions among various compounds in a waste, and there exist virtually no data on, or experience with, testing mixtures of chemicals for potential health and environmental effects. In some cases, data on individual compounds can be used for prediction.

The existing data on health and environmental effects of hazardous waste constituents only begin to address the various data needs concerning these issues that were listed in the previous section. The lack of progress in this area is becoming a major issue. For example, with regard to the CERCLA requirement for the formation of the Agency for Toxic Substances and Disease Registry in the Department of Health and Human Services, one of the originators of CERCLA has noted:

> Two years have passed since the law was enacted and virtually nothing which HHS was instructed to do has been done. As a result, the General Accounting Office is now investigating the Department's conduct (35).

A concern for the health and the safety of the environment is the driving force of hazardous waste management efforts. Unfortunately, the available information concerning the effects of hazardous substances on health and the environment is far from complete, and many of the issues involved are poorly understood. Hazardous waste management efforts—including regulation, the design and operation of facilities, siting, permitting, monitoring, and enforcement—are proceeding, even though they are sometimes based on perceptions rather than on sound data. The process of integrating health and environmental effects data into the design of management facilities, and using these data to control the operation of such facilities, is in its infancy. However, these efforts do not currently give sufficient consideration to health and the environment (see ch. 6 for greater detail regarding this issue).

Data Requirements: Management Facilities

Data related to management facilities are needed by government and industry. In many cases, the same data are used for different purposes.

Government needs data on facilities for effective regulation of them, for monitoring compliance with the regulations, for selecting fruitful areas for research and development (R&D), for actions required under CERCLA, and for providing information to the public. Government must respect the proprietary nature of much of this information.

In order to write regulations, data are required on available management technologies—their types and performance—and whether or not these technologies, in managing existing waste, can reduce exposure of people and the environment. This information, may lead to restricting certain types of waste to specific management technology design and performance standards (W, T).

In order to implement hazardous waste management regulations, data are required for the siting, permitting, and monitoring of facilities, and for monitoring the transportation of hazardous waste. Siting of facilities may be done by zoning certain land areas as appropriate to specific types of management technologies, or by selecting individual sites. Both environmental data and technology performance data are needed for zoning (T). In addition, the siting of an individual facility may require degree-of-risk data for the proposed facility (T, F).

The permitting process is the key to effective hazardous waste management and requires detailed facility data. These include the identification of management facilities, the nature and volume of the waste being managed, health and environmental impact data, the degree of risk offered by the proposed facility, and the financial capabilities of the facility operator to maintain the facility in the event of its closure, and for liability contingencies (F).

Monitoring the performance of waste management facilities requires data concerning both the facility itself and the surrounding environment. Data on the facility itself include visual inspection data (e.g., the detection of leaks or ruptures); process data (e.g., temperatures, flow rates, chemical concentration levels); and data concerning the nature of the release of substances from the facility to the environment—the characteristics of the substances released, the quantities released, and where, when, and in what manner environmental systems were exposed to these substances. Data on the ambient environment of the facility are required to track the long-term response to the released substances. The performance of the facility may have to be modified if these data show an unacceptable response (E, F).

To establish R&D priorities, technology data are required concerning the performance of available management technologies, and the level of performance improvement necessary to remove continuing threats to environmental and human safety.

For monitoring the transportation of hazardous waste from generators to offsite management facilities, various facility data are required (F). The characteristics of waste transported, along with the source and destination of transported waste should be determined. Data regarding transport vehicles (required to ensure that accidental releases of hazardous substances are minimized), dates of transportation and receipt, and the safety measures required in case of accidental release should be adequately defined.

Facility data will be needed to identify waste management facilities that may require cleanup action under CERCLA. These facility data may overlap somewhat with the data on hazardous waste management facilities regulated under RCRA.

Industrial data needs on facilities must be satisfied if industry is to play an effective role in hazardous waste management. Various types of data are required for the design of new management facilities and for decisions regarding the use of existing facilities for handling new waste. These data needs include:

- input waste characteristics and volume (F);
- design specifications—design standards and performance standards, both regulated and unregulated (T);
- potential of release of hazardous constituents into the environment and degree-of-risk data (F);
- health and environmental effects data (E, W);
- economic analysis of specific technologies (T);
- ability to reduce hazard level of waste or to adequately contain waste for a specified time period (F); and
- manpower required to operate the facility (F).

In the operation of management facilities, industry requires data in the following categories:

- input-output waste characteristics (F);
- day-by-day performance characteristics (F);
- ambient environment monitoring data (E);
- characteristics and quantity of waste in storage, and available storage capacities (F); and
- worker and environmental exposure to hazardous substances (F).

Facility data are also required to indicate areas and priorities for R&D. This need is similar to that described in government data needs, above. In planning for expansion, industry requires data including:

- amount of waste generated in a State or region of concern (W, S);
- existing management facilities, their capacity, and volume of waste throughput (F);
- available management alternatives for prospective generated wastes—e.g., material/energy recovery, incineration, storage (T);
- transportation needs (F); and
- availability of suitable sites (T, F).

The public needs data to understand what is proper waste management. The public should have easy access to nonproprietary data of the above types. In addition, information on monitoring and enforcement programs should be made available to the public.

RCRA mandated collection of information on waste management facilities in operation prior to RCRA permitting. Initially, these data were compiled from industry applications for hazardous waste permits, known as part A applications. Two subsequent surveys were conducted by EPA to determine the validity of these data. A number of additional efforts within the EPA Office of Solid Waste have attempted to identify hazardous waste management facilities. The best known of these efforts is a 1980 report (29), which was updated in 1982 (36). An ongoing survey effort, due in 1983, may provide additional detailed information on 2,500 hazardous waste management facilities. The latter data will be used as background information for the RCRA Regulatory Impact Analysis.

Facility information has also been gathered under other environmental laws. For instance, surface impoundment and open dump inventories have been conducted under the Safe Drinking Water Act and the solid waste provisions of RCRA, respectively. CERCLA requires the annual listing of at least 400 hazardous waste management facilities requiring priority remedial action. Facilities that discharge treated wastewater into the Nation's waters must obtain NPDES permits under the Clean Water Act. Inventories conducted under the authority of other environmental acts may provide qualitative measures of the accuracy of the part A submissions.

The part A data were compiled from industry information submitted in 1980, when EPA required all operating hazardous waste management facilities to submit an application for an interim status permit (37). The facilities that submitted applications were to be subjected to additional State and Federal reviews prior to receiving full permit status. Information from this data base has been used to formulate continuing surveys of facilities.

Problems inherent in this data base stem from confusion about the type of information requested. Information required included:

1. location and ownership of the facility;
2. function—storage, treatment, disposal;
3. types of technologies employed—e.g., landfill, surface impoundment, incinerator;
4. capacity of the facility;
5. types and quantities of waste throughput; and
6. whether and to what extent the facility was subject to regulation under other environmental acts.

Standardized measures (e.g., measures of capacity) and specified criteria were not required. Furthermore, definitions given in the application were poorly stated and space for responses was often inadequate. Approximately 10,200 responses were received by EPA, of which only some 60 percent included capacity data. Also, discussions with EPA personnel suggest that, in particular, responses to items 4 and 5 are unreliable. The completeness and accuracy of the information are, therefore, questionable. However, it may be necessary to use this information, since it is the best available.

The applications have been subjected to two telephone validation surveys (38). The first of these, covering approximately 700 facilities, indicated that the original part A data represented an overstatement of available hazardous waste management services. The results of the second survey, which reached about 85 percent of the facilities in the part A data base, are shown in tables 20 and 21. EPA's estimates of nationwide numbers of facilities, and waste throughput or technology capacity were derived with a methodology that allows for the fact that not all part A respondents were reached. Table 20 shows that an estimated total of 7,785 hazardous waste management facilities in nine technology classes were operating in the Nation in 1981. Waste throughput estimates were provided for seven of the nine technology types and facility capacity estimates were provided for two technology types (storage and treatment tanks). Due to incomplete data for both waste throughput and capacity, and because figures for all are given in inconsistent units of measure, no meaningful total national capacity or waste throughput estimates can be made for the hazardous waste management industry.

Table 21, derived from the part A data and its second validation, shows the estimated number of commercial offsite hazardous waste management facilities in the Nation during 1981, the estimated waste throughput for the first seven technology types, the estimated facility capacity for the last two technology types, and the estimated proportion of total na-

Table 20.—Hazardous Waste Management Facilities During 1981 (regulated under RCRA)

Technology type	Original Part A data	Estimated number of sites	Estimated total
			Waste throughput
Injection wells	159	114	3.5 billion gal
Landfills	545	270	8.3 million tons
Land treatment	222	148	8,600 acres[a]
Surface impoundments	1,754	1,096	28.8 million square yards[a]
Waste piles	585	312	13.2 million cubic yards[a]
Incinerators	608	317	272 million gal
Storage containers	7,551	5,652	57 million gal
			Estimated capacity
Storage tanks	4,230	2,280	303 million gal
Treatment tanks	3,013	1,951	3.1 billion gal
Total	10,247	7,785	n/a

[a] Westat's questionnaire requested throughput data; the figures given in units of area do not represent either throughput or capacity.

SOURCE: Westat and EPA, 1982.

Table 21.—Number and Size of Commercial Offsite Facilities During 1981
(regulated under RCRA)

Technology	Estimated total number	Estimated total during 1981	Percent of national facilities
		Waste throughput	
Injection wells	4	n/a	n/a
Landfills	54	2.1 million tons	25.0
Land treatment	11	276.1 acres[a]	3.2
Surface impoundments	29	1.1 million square yards[a]	3.8
Waste piles	5	n/a	n/a
Incinerators	43	n/a	n/a
Storage containers	49	860,000 gal	1.5
		Estimated capacity	
Storage tanks	47	15 million gal	4.9
Treatment tanks	22	7.1 million gal	0.2
Total	125	n/a	n/a

[a] Westat's questionnaire requested throughput data; the figures given in units of area cannot represent either throughput or capacity and therefore appear to be meaningless.

SOURCE: Westat and EPA, 1982.

tional waste throughput or waste management capacity at these facilities. An estimated total for 125 such facilities is given. Commercial offsite facilities represented in table 21 are defined as "those facilities that reported generating a low percentage (10 percent or less) of the hazardous waste they handled in 1981 and indicated that commercial waste management was the primary activity at the site" (37).

In 1980, EPA released a report that estimated the availability of offsite commercial hazardous waste management services, which constitute a small subset of total hazardous waste management capacity. In the context of the EPA report, the term "commercial facilities" includes facilities engaged in treatment and disposal for fee, but excludes waste oil rerefiners, resource recovery facilities, storage and transfer stations, waste brokers, conventional sanitary landfills, and publicly owned wastewater treatment works" (29). The report was intended to enable EPA to evaluate various regulatory alternatives that influence demand for offsite waste management services. The report provides estimates for the number and capacity of existing commercial hazardous waste management in the Nation, and for needed additional national and regional hazardous waste management capacity by technology type.

The report provides only general indications of its sources of information—EPA files, industry service directories, and telephone surveys. The capacities of facilities failing to respond were computed using data from similar facilities. The report considers 127 commercial facilities, roughly 50 percent of the commercial facilities submitting part A applications, but all of the commercial facilities according to the recent validation study noted above. It does not contain data on any onsite management facilities, or generator-owned offsite facilities. The report estimated that the commercial facilities (about 2 percent of total hazardous waste management facilities) represented about 20 percent of available national hazardous waste management capacity. This is consistent with the generally accepted view that usually about 15 to 30 percent of hazardous waste in a State are managed offsite.

Total national and regional management facility capacity needs for the early 1980's are also estimated by technology type. The report indicates that, while adequate hazardous waste management capacity currently exists in the Nation, it may be poorly distributed relative to generation.

In 1982, Booz Allen and Hamilton (36) updated their previous report (29). This update considered the activities of only nine firms operating 46 commercial facilities. This updated report discusses the activities of these facilities during 1981, and the effect of EPA regulations on those activities, but gives no further insight into the national or regional character of the overall hazardous waste management industry. It does indicate, however, that capacity utilizations in 1981 were relatively low, which is consistent with lowered rates of waste generation in recent years resulting from lowered levels of industrial activity.

Management facility data have also been collected in studies performed for the States. However, only a fraction of the States appear to have collected such data: California, Louisiana, Michigan, New Jersey, North Carolina, and Texas. While currently limited, State data will be improved progressively through the permitting process. Presently, few States have received EPA authorization to implement permitting programs. These States that have received this authority (by October 1982) are Arkansas, Georgia, Mississippi, North Carolina, South Carolina, and Texas. Oklahoma's authorization is due in late 1982. Extant State data on management facilities have not been analyzed by OTA.

CERCLA Sites.—National estimates of the number of sites that contain hazardous waste and that may require cleanup, have been provided by two studies: an EPA consultant report by Fred C. Hart Associates (39) and a report by the Chemical Manufacturers Association (CMA) (40). Their estimates of the number of sites range from 4,800 (the CMA study) to 30,000 to 50,000 sites (the EPA consultant estimate). The CMA estimate was based on a telephone survey of the States, but does not say how many States provided data, or how the States that did respond derived their figures. The EPA consultant report was derived from compilations of data provided by EPA Regional Offices, but no consistent methodology appears to have been employed by these offices. Few of the sites were visited during the course of the EPA consultant study. In February 1983, EPA had about 15,000 uncontrolled sites in its national inventory. According to EPA data, preliminary assessments had been carried out for only 14 percent of the sites, and site inventories had been completed for 2 percent of the sites in the inventory as of December 1982.

In 1982, EPA published a list of 115 hazardous waste disposal sites as the interim national priority CERCLA sites. This list was later extended by 45 additional priority sites that were judged also to pose substantial threats to health and the environment. EPA's methodology for ranking uncontrolled sites is discussed in some detail in chapter 6. In December 1982, EPA released the first complete National Priority List of 418 sites, and intends to periodically update this list.

Summary.—The existing facilities data described above do little to satisfy the data needs of government, industry, and the public concerning management facilities. The only need that these existing data do satisfy (and then only marginally) is that of identification of management facilities and the technologies they employ.

A significant quantity of required technology level data (T) are available to industry, government, and the public. These data are discussed in chapter 5.

The required facility level data (F) that currently exist are largely in the hands of industry. Much of these data will progressively pass to government, and some in turn to the public, as a result of the permitting process.

Existing EPA facilities data is being used as a source, for the States and EPA, of names and addresses of facilities that may require permitting by the States. The determination of a given facility's need for a permit, the process of issuing the permit, and the monitoring of the facility's compliance to the requirements of the permit all require data beyond the scope of the validated part A data.

The data are also used as a source by the public, of facilities that have reported to EPA an involvement in hazardous waste management. This information provides communities with a primary focus for local concerns about the management of hazardous waste. It also enables communities, concerned about the presence and operation of a given waste management facility, to determine whether EPA or the State currently recognizes that facility as handling hazardous waste—facilities not so recognized will not be permitted and regulated.

These EPA data resources are also used to identify those management facilities that are offsite or commercial facilities, and are therefore receiving transported hazardous waste. This information might be useful to the transportation industry in its market surveys. It might be useful to the public because it defines where hazardous waste is going. In addition, such information should prove useful to the States in their efforts to establish manifest systems to regulate the transportation of hazardous waste.

The waste throughput and capacity estimates included in the EPA data appear to have little practical use. These data are incomplete. They appear to represent capacity for managing both hazardous waste (as defined by EPA) and other solid waste, as well as hazardous waste defined differently by States, or to represent total waste throughput while not distinguishing hazardous waste from other waste. Moreover, even though the data are for facility and technology type, they do not indicate what waste constituents can be managed in each facility. **Consequently, it is not possible to compare the quantity of a given type of waste generated in the Nation, or in any State, with the capacity available to manage it.** In some cases, the units of measurement for throughput reported in the national data are simply inappropriate. For example, surface impoundment "waste throughput" is reported in units of area (square yards). The appropriate measure of the quantity of waste that might be treated in such a way would be volume per year (gallons per year). Since evaporation—and perhaps drainage and leaching— continually decreases the volume of waste in a surface impoundment, an appropriate and useful measure of surface impoundment throughput would be the waste **input** volume per year that the impoundment could handle, or the waste **input** weight per year. Similar attention to appropriate units must be given to capacity data whenever these are collected.

If both management capacity data (in the appropriate units) and waste throughput data (in the same units) were available at a facility and technology level for the Nation, and if these data indicated the waste constituents to which the capacity and waste throughput figures applied, then such data could serve several purposes. Both government and industry could determine the distribution of hazardous waste among management technology settings. This data, in concert with other information, would provide a basis for assessing the impact of regulations on a given technology class. However, EPA does not dispute the generally held view, based on its early and more recent data, that as much as 80 percent of hazardous wastes continue to be disposed or dispersed in or on the land.* Also, both government and industry could ascertain those management facilities that were operating near maximum capacity. This would indicate management facilities requiring expansion, and the level of expansion required by an increase in production of waste of the type handled by those facilities, or by the closing of management facilities handling similar waste. Government and industry could also gauge the expansion of the various waste generating industries that could occur without a need for expansion of corresponding waste management industries and could determine fruitful areas for R&D. Such R&D could lead to modifications of industrial processes that generate waste in a manner that would reduce the quantities of certain types of generated waste, thereby reducing loads on the management facilities that handle that waste. Such modifications could be based on both waste generation and management data of the facility type. Research and development could also lead to new management technologies to handle types of generated waste not adequately handled in existing facilities. This requires detailed generation data, management technology data, and health and environmental effects data.

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*For example, 83 percent of the hazardous waste generated by 14 industries were placed in or on the land, based on 1975-78 data. ("Subtitle C - RCRA Draft Final Environmental Impact Statement—Part I," EPA, April 1980) This figure appears consistent with EPA's statements concerning the fraction of hazardous waste properly managed: "Less than 10 percent of these hazardous manufacturing wastes are estimated to have been treated/disposed in an environmentally adequate manner." ("RCRA Subtitle C—Hazardous Waste Management: Regulatory Analysis," EPA, Apr. 30, 1980.) The recent validation survey of management facilities indicated that in 1981 about 20 million tonnes of hazardous waste were disposed in injection wells and landfills, but no data were available for other forms of land disposal such as land treatment and surface impoundments or for ocean disposal; therefore, there is confirmation that more than half of currently generated waste are placed into the environment. The ASTSWMO survey also provided some data on land disposal. For example, 1981 data for Louisiana indicates that 97 percent of waste managed offsite are land disposed, and that about 50 percent of the waste managed onsite (99 percent of total) are land disposed. Recent data for Texas indicates that 95 percent of their hazardous waste enter the land, but in Missouri and Massachusetts only 40 and 7 percent, respectively, is land disposed.

Another benefit of R&D would be the conservation of national resources. **The national view of management facility activities may well identify substantial quantities of energy and materials that could be recovered in a cost-effective manner, rather than being lost in the process of treatment and disposal.** The data necessary for these purposes could be collected by EPA through national surveys or could be obtained through the States by means of State surveys and the facility permitting process. Clearly, the uses noted for such data could also be made of any set of State data of the facility and technology types.

It is clear that the information concerning sites containing hazardous waste that may pose a threat to health and the environment is inadequate both from the standpoints of validity and immediate usefulness. Information previously collected by EPA, the States, and industry (39,40) serves as a starting point for investigations preliminary to cleanup. This is, in fact, how the data are being used. However, little information appears to be available about the specific waste contained in these sites, the technologies employed in the facilities, or the risk to health and the environment posed by waste management practices. Such data are fundamental to evaluations preliminary to cleanup activities.

Priorities for Data Acquisition

The foregoing discussion has indicated that a large discrepancy exists between the data required for effective hazardous waste management and that existing at various levels. Considerable effort is required if this discrepancy is to be removed, and the task must be approached with urgency if damage to health and the environment is to be minimized.

The following data are considered to have the highest priority in this data acquisition effort.

- **Health and environmental effects data.**—A sound understanding of the effects of hazardous waste on human health and the environment is essential for effective hazardous waste management. It enables the identification of hazardous substances and their relative hazards, assists in setting design and performance standards for management facilities, provides meaningful reference data with which to evaluate monitoring data, and provides the assurance that management measures adopted are indeed sufficient (see ch. 6).
- **Facility data concerning hazardous waste generators and management facilities.**—Identification by government of all hazardous waste generators and the volume and nature of their waste is crucial if the problem of hazardous waste is to be fully addressed. Control of management facilities is crucial—this will be possible through the permitting of such facilities.
- **Current data for each available hazardous waste management technology.**—This data on technologies would include information concerning, primarily, **performance** and **degree of risk**. The relationships between input waste characteristics

and output residual waste and effluent characteristics. These data may be used to emphasize the capabilities and limitations of certain technologies to handle particular types of waste, as well as areas that require further R&D (see ch. 5). Though of less importance than performance data in the short term, degree of risk data that addresses site-specific factors are desirable in the long term for effective and reliable management (see ch. 6).

- **Data suitable for establishing facility design and performance standards.**—These standards must be periodically updated to reflect growing knowledge of health and environmental effects, and to take advantage of evolving management technologies (see ch. 5).
- **Data concerning alternative industrial processes** (in waste generation industries) that reduce the volume and hazard of waste (see ch. 5).
- **Data concerning the costs, to industry and government, of implementing regulations governing hazardous waste management.**—(Unit cost data for management options are discussed in ch. 5, and national industry and government costs are discussed in ch. 7.)
- **Data concerning CERCLA sites.**—Data are needed on the wastes deposited in the sites, the technologies employed, the risks associated with the continued residence of waste in these sites, and the risks associated with remedial activities at the sites. A systematic investigation of sites is needed and will require extensive financial and manpower resources (see ch. 5).*

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*Congress recognized this problem and appropriated $10 million from CERCLA funds for sec. 3012 of RCRA for fiscal year 1983. States will receive these funds to develop inventories of hazardous waste sites that may require CERCLA attention. However, the implementation plan by EPA is not focused on discovering new sites, but on gathering more information on known uncontrolled sites.

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3. Ibid., sec. 1004 (5).
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CHAPTER 5

Technologies for Hazardous Waste Management

Summary Findings

Waste Reduction Alternatives

- **Source segregation** is the easiest and most economical method of reducing the volume of hazardous waste. This method of hazardous waste reduction has been implemented in many cases, particularly by large industrial firms. Many opportunities still exist for further application. Any change in management practices should include the encouragement of source segregation.
- Through a desire to reduce manufacturing costs by using more efficient methods, industry has implemented various **process modifications.** Although a manufacturing process often may be used in several plants, each facility has slightly different operating conditions and designs. Thus, a modification resulting in hazardous waste reduction may not be applicable industrywide. Also,proprietary concerns inhibit information transfer.
- **Product substitutes** generally have been developed to improve performance. Hazardous waste reduction has been a side-benefit, not a primary objective. In the long term, end-product substitution could reduce or eliminate some hazardous wastes. Because many different groups are affected by these substitutions, there are limitations to implementation.
- With regard to **recovery and recycling** approaches to waste reduction, if extensive recovery is not required prior to recycling a waste constituent, in-plant operations are relatively easy. Commercial recovery benefits are few for medium-sized generators. No investment is required, but liability remains with the generator. Commercial recovery has certain problems as a profitmaking enterprise. The operator is dependent on suppliers' waste as raw material; contamination and consistency in composition of a waste are difficult to control. Waste exchanges are not very popular at present, since generators must assume all liability in transferring waste. Also, small firms do not generate enough waste to make it attractive for recycling.

Hazard Reduction Alternatives: Treatment and Disposal

- Many waste treatment technologies can provide **permanent, immediate,** and very **high degrees** of hazard reduction. In contrast, the long-term effectiveness of land-based disposal technologies relies on **continued** maintenance and integrity of engineered structures and proper operation. For wastes which are toxic, mobile, persistent, and bioaccumulative, and which are amenable to treatment, hazard reduction by treatment is generally preferable to land disposal. In general, however, costs for land disposal are comparable to, or lower than, unit costs for thermal or chemical treatment.
- For waste disposal, advanced landfill designs, surface impoundments, and injection wells are likely to perform better than their earlier counterparts. However, there is insufficient experience with these more advanced designs to predict their performance. Site- and waste-specific factors and continued maintenance of final covers and well plugs will be important. The ability to evaluate the effectiveness of these disposal technologies could be improved through better instrumentation of these facilities. Currently, their performance evaluation relies heavily on monitoring the indirect effects of their failure by, for example, detecting aquifer contamination.
- In comparing waste treatment to disposal alternatives, the degrees of permanent hazard reduction immediately achievable with treatment technologies are overwhelming attributes in comparison to land-based dispos-

al. However, comparison of these technologies at the very high destruction levels they achieve is difficult. Difficulties include: monitoring methods and detection limits, knowledge about the formation of toxic products of incomplete combustion, and diversity in performance capabilities among the different treatments.

- Chemical, physical, and biological **batch-type treatment processes** can be used to reduce waste generation or to recover valuable waste-stream constituents. In marked contrast to both incineration and land disposal, these processes allow checking treatment residuals before any discharge to the environment. In general, processes which offer this important added reliability are few, but waste-specific processes are emerging. **Research and development efforts could encourage the timely emergence of more of this type process applicable to future hazardous wastes.**

Ocean Use

- For some acids and very dilute other hazardous wastes, dumping in ocean locations may offer acceptable levels of risk for both the ocean environment and human health. However, there is generally inadequate scientific information for decisions concerning most toxic hazardous wastes and most locations. This is a serious problem since there may be increasing interest in using the oceans as the costs of land disposal increase and if public opposition to siting new treatment facilities continues.

Uncontrolled Sites

- A major problem is that the National Contingency Plan under the Comprehensive Environmental, Response, Compensation, and Liability Act (CERCLA) does not provide specific standards, such as concentration limits for certain toxic substances, to establish the extent of cleanup. There are concerns that cleanups may not provide protection of health and environment over the long term.
- The long-term effectiveness of remedial technologies is uncertain. A history of effectiveness has not yet been accumulated. Many remedial technologies consist of waste containment approaches which require long-term operation and maintenance. In recent remedial actions, removal of wastes and contaminants, such as soil, accounted for 40 percent of the cases; such removed materials were usually land disposed.

Introduction

The purpose of this chapter is to describe the variety of technical options for hazardous waste management. The technical detail is limited to that needed for examining policy options and regulatory needs. Still, there are many technologies, and their potential roles in hazardous waste management are diverse. Thus, there are many technical aspects related to policy and regulation issues. The reader interested in the details of the technologies reviewed here is encouraged to read beyond this policy-oriented discussion.

The first group of technologies discussed are those which reduce waste volume. This distinction recognizes that where technically and economically feasible, it is better to reduce the generation of waste than to incur the costs and risks of managing hazardous waste. **Waste reduction** technologies include segregation of waste components, process modifications, end-product substitutions, recycling or recovery operations, and various emerging technologies. Many waste reduction technologies are closely linked to manufacturing and involve proprietary information. Therefore, there is less detailed information in this section than in others.

Much of the chapter discusses technologies that reduce the hazard from the waste generated. These are grouped as: 1) those **treatments that permanently eliminate the hazardous character** of the material, and 2) those **disposal approaches that contain** or immobilize the hazardous constituents.

There are several treatments involving high temperature that decompose materials into harmless constituents. Incineration is the obvious example, but there are several existing and emerging "destruction" technologies that are distinguished in this category. In addition to gross decomposition of the waste material, there are emerging chemical technologies which detoxify by limited molecular rearrangement and recover valuable materials for reuse. Whether by destruction or detoxification, these technologies permanently eliminate the hazard of the material.

Containment chiefly involves land disposal techniques, but chemical "pretreatment" methods for stabilization on a molecular level are rapidly emerging. Combining these methods offers added reliability, and sectors of industry appear to be adopting that approach. The discussion of containment technologies includes: 1) landfilling, 2) surface impoundments, 3) deep-well injection, and 4) chemical stabilization.

Use of the oceans is considered a technical option for some wastes. A number of regulatory and policy issues emerge concerning ocean use and are discussed.

The final section of this chapter concerns uncontrolled hazardous waste sites from which releases of hazardous materials is probable or has already occurred. Such sites are often abandoned and are no more than open dumps. The sites are addressed by CERCLA. The technical aspects of identifying, assessing, and remediating uncontrolled sites are reviewed in this section. There has been limited engineering experience with cleaning up uncontrolled sites.

Many technologies that are applicable to the same waste compete in the marketplace. The initial discussion in the section on hazard reduction treatment and disposal technologies compares the costs of comparative technologies in some detail.

Waste Reduction Alternatives

Introduction

Four methods are available to reduce the amount of waste that is generated:

1. source segregation or separation,
2. process modification,
3. end-product substitution, and
4. material recovery and recycling.

Often, more than one of these approaches is used, simultaneously or sequentially.

Reduction of the amount of waste generated at the source is not a new concept. Several industrial firms have established in-house incentive programs to accomplish this. One example is the 3P program—Pollution Prevention Pays—of the 3M Corp. Through the reduction of waste and development of new substitute products for hazardous materials, 3M has saved $20 million over 4 years.[1] Other firms have established corporate task forces to investigate solutions to their hazardous waste management problems. One solution has been recycling and recovery of waste generated by one plant for use as a raw material at another corporate-owned facility. Such an approach not only reduces waste, but lowers operating costs.

Significant reductions in the volume of waste generated can be accomplished through source segregation, process modification, end-product substitution, or recovery and recycle. No one method or individual technology can be selected as the ultimate solution to volume reduction. As shown in figure 7, three of the methods, i.e., source segregation, process modifica-

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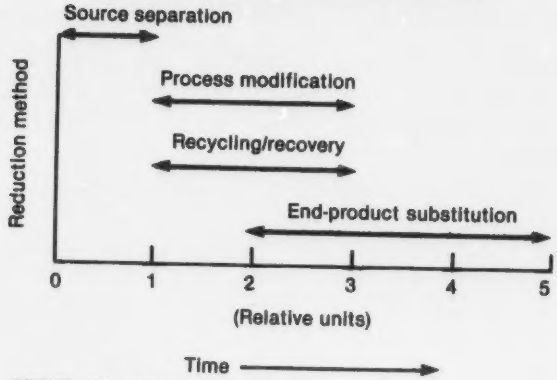
[1] M. G. Royston, *Pollution Prevention Pays* (New York: Pergamon Press, 1979).

Figure 7.—Relative Time Required for Implementation of Reduction Methods



SOURCE: Office of Technology Assessment.

tions, and recovery and recycling can be implemented on a relatively short- to medium-term basis by individual generators. End-product substitution is a longer term effort. A comparison of the advantages and disadvantages of each of the four approaches is given in table 22. Because of proprietary concerns and lack of industrywide data, the amount of waste reduction that has already occurred and the potential for further reduction is difficult to evaluate. A 1981 study by California[2] concluded that new industrial plants will produce only half the amount of hazardous waste currently produced. Other estimates for potential waste production range from 30 to 80 percent.[3] Waste reduction efforts, however, are more difficult in existing plants.

Source Segregation

Source segregation is the simplest and probably the least costly method of reduction. This approach prevents contamination of large vol-

Table 22.—A Comparison of the Four Reduction Methods

Advantages	Disadvantages
Source segregation or separation	
1) Easy to implement; usually low investment 2) Short-term solution	1) Still have some waste to manage
Process modification	
1) Potentially reduce both hazard and volume 2) Moderate-term solution 3) Potential savings in production costs	1) Requires R&D effort; capital investment 2) Usually does not have industrywide impact
End product substitution	
1) Potentially industrywide impact—large volume, hazard reduction	1) Relatively long-term solutions 2) Many sectors affected 3) Usually a side benefit of product improvement 4) May require change in consumer habits 5) Major investments required—need growing market
Recovery/recycling	
• *In-plant*	
1) Moderate-term solution 2) Potential savings in manufacturing costs 3) Reduced liability compared to commercial recovery or waste exchange	1) May require capital investment 2) May not have wide impact
• *Commercial recovery (offsite)*	
1) No capital investment required for generator 2) Economy of scale for small waste generators	1) Liability not transferred to operator 2) If privately owned, must make profit and return investment 3) Requires permitting 4) Some history of poor management 5) Must establish long-term sources of waste and markets 6) Requires uniformity in composition
• *Waste exchange*	
1) Transportation costs only	1) Liability not transferred 2) Requires uniformity in composition of waste 3) Requires long-term relationships—two-party involvement

SOURCE: Office of Technology Assessment.

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[2] "Future Hazardous Waste Generation in California," Department of Health Services, Oct. 1, 1982.

[3] Joanna D. Underwood, Executive Director, Inform, *The New York Times*, Dec. 27, 1982.

umes of nonhazardous waste by removal of hazardous constituents to form a concentrated hazardous waste. For example, metal-finishing rinse water is rendered nonhazardous by separation of toxic metals. The water then can be disposed through municipal/industrial sewage systems.

However, there are disincentives, particularly for small firms wishing to implement source segregation. For example, an electroplating firm may, for economic reasons, mix wastes containing cyanides and toxic metals with a waste that contains organics. The waste stream is sent to the municipal treatment system. The municipal system can degrade the organics, but the metals and cyanide accumulate in the sludge, which is disposed as a nonhazardous solid waste in a sanitary landfill. As long as the firm dilutes the cyanide and metals concentrations to acceptable limits for municipal disposal, it is in compliance with the Environmental Protection Agency's (EPA) regulations. If the firm calculates the costs of recovering the cyanide onsite, the cost may be more than the fees paid to the municipal treatment facility. Thus, there is no economic incentive for source segregation, which would yield a hazardous waste, although the public would benefit if source segregation were practiced. Alternatively, accumulation of such sludges can lead to significant levels of toxic material in sanitary landfills. Municipal treatment facilities are financed with tax dollars. In this example, the public is, in essence, subsidizing industrial waste disposal. Moreover, to carry out source segregation, a firm may have to invest in new equipment.

Process Modification

Process modifications are, in general, made on a continuous basis in existing plants to increase production efficiencies, to make product improvements, and to reduce manufacturing costs. These modifications may be relatively small changes in operational methods, such as a change in temperature, in pressure, or in raw material composition, or may involve major changes such as use of new processes or new equipment. Although process modifications have reduced hazardous wastes, the reduction usually was not the primary goal of the modifications. However, as hazardous waste management costs increase, waste reduction will become a more important primary goal.

Three case examples were studied to analyze incentives and impacts for process modifications for hazardous waste reduction. The following factors are important:

- A typical process includes several steps. Although a change in one step may be small relative to the entire process, the combination of several changes often represents significant reductions in cost, water use, or volume of waste.
- A change in any step can be made independently and is evaluated to determine the impact on product, process efficiency, costs, labor, and raw materials.
- Generally, process modifications are plant- or process-specific, and they cannot be applied industrywide.
- A successful process change requires a detailed knowledge of the process as well as a knowledge of alternative materials and processing techniques. Successful implementation requires the cooperative efforts of material and equipment suppliers and in-house engineering staffs.

Three process changes are discussed in detail in the appendix to this chapter and are briefly summarized below:

1. **Chlor-alkali industry.**—Significant process developments in the chlor-alkali industry (which produces, e.g., chlorine and caustic soda) have resulted in reduction of major types of hazardous waste through modifications to the mercury electrolysis cell. The effects on waste generation are summarized in table 23. The modifications were not developed exclusively to reduce hazardous waste, but were initiated primarily to increase process efficiency and reduce production costs.
2. **Vinyl chloride (plastics) production.**—Several process options are available for handling waste from the production of vinyl chloride monomers (VCMs). Five al-

Table 23.—Process Modifications to the Mercury Cell

Modification	Effect on waste stream	Reason for modification
Diaphragm cell	Elimination of mercury contaminated waters	Preferred use of natural salt brines as raw material
Dimensionally stable anode	Elimination of chlorinated hydrocarbon waste	Increased efficiency
Membrane cell	Elimination of asbestos diaphragm waste	Reduce energy costs; higher quality product

SOURCE: Office of Technology Assessment.

ternatives are illustrated in table 24. All five have been demonstrated on a commercial scale. In most cases, the incineration options (either recycling or add-on treatment) would be selected over chlorinolysis and catalytic fluidized bed reactors. Chlorinolysis has limited application because of the lack of available markets for the end products. If further refinements could be made to the catalytic process, such as higher concentration of hydrogen chloride (HCl) in the gas stream which would allow it to be used with all oxychlorination plants, its use could be expanded.

3. **Metal-finishing industry.**—Several modifications in metal cleaning and plating processes have enabled the metal-finishing industry to eliminate requirements for onsite owned and operated wastewater treatment facilities. By changing these processes to eliminate formation of hazardous sludge, the effluent can be discharged directly to a municipal wastewater treatment facility, saving several million dollars in capital investment.

End-Product Substitution

End-product substitution is the replacement of hazardous waste-intensive products (i.e., industrial products the manufacture of which involves significant hazardous waste) by a new product, the manufacture of which would eliminate or reduce the generation of hazardous waste. Such waste may arise from the ultimate disposal of the product (e.g., asbestos products) or during the manufacturing process (e.g., cadmium plating).

Table 25 illustrates six examples of end-product substitution, each representing a different type of problem. General problems include the following:

Table 24.—Advantages and Disadvantages of Process Options for Reduction of Waste Streams for VCM Manufacture

Treatment option	Type	Advantages	Disadvantages
High-efficiency incineration of vent gas only	Add-on treatment	1. Relatively simple operation 2. Relatively low capital investment	1. Second process required to handle liquid waste stream
High-efficiency incineration without HCl recovery	Add-on treatment	1. Relatively simple operation 2. Relatively low capital investment	1. Loss of HCl
High-efficiency incineration with HCl recovery	Recycling	1. Heat recovery 2. Recover both gaseous and liquid components 3. High reliability	1. Exit gas requires scrubbing 2. Requires thorough operator training 3. Auxiliary fuel requirements
Chlorinolysis	Modification of process	1. Carbon tetrachloride generated	1. High temperatures and pressures required 2. High capital investment costs 3. Weakening market for carbon tetrachloride
Catalytic fluidized bed reactor	Recycling	1. Low temperature 2. Direct recycle of exit gas (no treatment required)	1. Limited to oxychlorination plants

SOURCE: Office of Technology Assessment.

Table 25.—End-Product Substitutes for Reduction of Hazardous Waste

Product	Use	Ratio of waste:[a] original product	Available substitute	Ratio of waste:[a] substitute product
Asbestos	Pipe	1.09	Iron	0.1 phenols, cyanides,
			Clay	0.05 fluorides
			PVC	0.04 VCM manufacture + 1.0 PVC pipe
	Friction products (brake linings)	1.0+ manufacturing waste	Glass fiber Steel wool Mineral wools Carbon fiber Sintered metals Cement	0
	Insulation	1.0+ manufacturing	Glass fiber Cellulose fiber	0.2
PCBs	Electrical transformers	1.0	Oil-filled transformers	0
			Open-air-cooled transformers	0
Cadmium	Electroplating	0.29	Zinc electroplating	0.06
Creosote treated wood	Piling		Concrete, steel	0.0 (reduced hazard)
Chlorofluorocarbons	Industrial solvents	70/81 = 0.9	Methyl chloroform; methylene chloride	0.9 (reduced hazard)
DDT	Pesticide	1.0+ manufacturing waste	Other chemical pesticides	(reduced hazard) 1.0+ manufacturing waste

[a] Quantity of hazardous waste generated/unit of product

SOURCE: Office of Technology Assessment.

- **Not all of the available substitutes avoid the production of hazardous waste.** For example, in replacing asbestos pipe, the use of iron as a substitute in pipe manufacturing generates waste with phenols and cyanides; and also, during the manufacture of polyvinyl chloride (PVC) pipe, a hazardous vinyl chloride monomer is emitted.[4]
- **Substitution may not be possible in all situations.** For example, although a substantial reduction in quantity of hazardous waste generated is achieved by using clay pipes, clay is not always a satisfactory replacement for asbestos.[5]

Generally, development of substitutes is motivated by some advantage, either to a user, (e.g., in improved reliability, lower cost, or easier operation), or to the manufacturer (e.g., reduced production costs). A change in consumer behavior also may cause product changes. For example, increased use of microwave ovens has increased the demand for paper and Styrofoam packaging to replace aluminum. Most end-product substitutions aimed at reduced generation of hazardous waste, however, do not have such advantages. The only benefit may be reduction of potential adverse effects on human health or the environment. Unless the greater risks and costs of hazardous waste management are fully internalized by waste generators, other incentives may be needed to accomplish end-product substitution.

In addition to the approach in chapter 3, option III, end-product substitution may be encouraged by:

1. regulations,
2. limitation of raw materials,
3. tax incentives,
4. Federal procurement practices, and
5. consumer education.

Regulations have been used to prohibit specific compounds. For example, bans on certain pesticides such as dichlorodiphenyltrichloroethane (DDT) have resulted in development and use of other chemicals. Legislative prohibition of specific chemicals, such as polychlorinated biphenyls (PCBs), is another option.

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[4] Sterling-Hobe Corp., *Alternatives for Reducing Hazardous Waste Generation Using End-Product Substitution*, prepared for Materials Program, OTA, 1982.

[5] Ibid.

Limiting the supply of raw materials required for manufacture is another method of encouraging end-product substitution. For example, limiting either the importation or domestic mining of asbestos might encourage substitution of asbestos products. A model for this method is the marketing-order system of the U.S. Department of Agriculture, used to permit the cultivation of only specified quantities of selected crops. Using similar strategies, a raw material like asbestos could be controlled by selling shares of a specified quantity of the market permitted to be mined or imported.

Tax incentives are another means to force end-product substitution. Excise taxes on products operate as disincentives to consume and have been implemented in the past (e.g., taxes on alcohol, cigarettes and gasoline). This type of taxation might be incorporated to encourage product substitution. The design and acceptance of a workable, easily monitored tax system, however, might be difficult to develop.

Federal procurement practices and product specifications can have significant influence on industrial markets. Changes in military procurement were proposed in 1975 to allow for substitution of cadmium-plating by other materials. A change in product specifications to permit this substitution would affect not only the quantity of cadmium required for military use, but also might impact nonmilitary applications.

A public more aware of the hazard associated with production of specific products might be inclined to shift buying habits away from them.

Larger Economic Contexts.—If a substitution requires a complete shift in industrial markets (e.g., if a product manufactured with asbestos is replaced by one made with cement), the impact may be large—both manufacturers and suppliers may be affected. In addition, users will be impacted according to the relative merits of the products. Other sectors potentially affected by end-product substitution include importers of raw materials, exporters of the original product, and related equipment manufacturers.

Generally, a product substitution offers a cost advantage over the original product, which counters market development expenditures. Potential savings can be achieved by the introduction of product substitutes—e.g., increased demand may require increased production, thus reducing the cost per unit. Incentives or the removal of disincentives, however, may be necessary to increase product demand by a sufficient margin to give the substitute a more competitive marketplace position.

A significant factor in the introduction of a substitute product is the stage of growth for existing markets. For example, if the market for asbestos brake lining is declining or growing at a very slow rate, or if large capital investments are required for development of a substitute lining, introduction of a substitute may not be economically practical. The availability of raw materials also affects the desirability of substitutes. If the original product is dependent on limited supplies of raw materials, substitutes will be accepted more rapidly.

Recovery and Recycling

Recovery of hazardous materials from process effluent followed by recycling provides an excellent method of reducing the volume of hazardous waste. These are not new industrial practices. Recovery and recycling often are used together, but technically the terms are different. Recovery involves the separation of a substance from a mixture. Recycling is the use of such a material recovered from a process effluent. Several components may be recovered from a process effluent and can be recycled or discarded. For example, a waste composed of several organic materials might be processed by solvent distillation to recover halogenated organic solvents for recycling; the discarded residue of mixed organics might be burned for process heat.

Materials are amenable to recovery and recycling if they are easily separated from process effluent because of physical and/or chemical differences. For example, inorganic salts can be concentrated from aqueous streams by evaporation. Mixtures of organic liquids can be separated by distillation. Solids can be separated from aqueous solutions through filtration. Further examples of waste streams that are easily adaptable to recovery and recycling are listed in table 26.

Recovery and recycling operations can be divided into three categories:

1. **In-plant recycling** is performed by the waste (or potential waste) generator, and is defined as recovery and recycling of raw materials, process streams, or byproducts for the purpose of prevention or elimination of hazardous waste. (Energy recovery without materials recovery is not included in this discussion of in-plant recycling, but is discussed later in this chapter as a **treatment** of wastes.) If several products are produced at one plant by various processes, materials from the effluents of one process may become raw materials for another through in-plant recycling. An example is the recovery of relatively dilute sulfuric acid, which is then used to neutralize an alkaline waste. In-plant recycling offers several benefits to the manufacturer, including savings in raw materials, energy requirements, and disposal or treatment costs. In addition, by reducing or eliminating the amount of waste generated, the plant owner may be exempted from some or all RCRA (Resource Conservation and Recovery Act) regulations.
2. **Commercial (offsite) recovery** can be used for those wastes combined from several processes or produced in relatively small quantities by several manufacturers. Commercial recovery means that an agent other than the generator of the waste is handling collection and recovery. These recovery systems may be owned and operated by, or simply serve, several waste generators, thereby offering an advantage of economy of scale. In most cases commercial recovery systems are owned and operated by independent companies, and are particularly important for small waste generators. In commercial recovery, responsibility for the waste and compliance with regulations and manifest systems remains that of the generator until recovery and recycling is completed.
3. **Material exchanges** (often referred to as "waste" exchanges) are a means to allow raw materials users to identify waste generators producing a material that could be used. Waste exchanges are listing mechanisms only and do not include collection, handling, or processing. Although benefits occur by elimination of disposal and treatment costs for a waste as well as receipt of cash value for a waste, responsibility for meeting purchaser specifications remains with the generator.*

Standard technologies developed that can be adapted for recovery of raw materials or byproducts may be grouped in three general cate-

Table 26.—Commercially Applied Recovery Technologies

Generic waste	Typical source of effluent	Recovery technologies
Solids in aqueous suspension	Salt/soda ash liming operations	Filtration
Heavy metals	Metal hydroxides from metal-plating waste; sludge from steel-pickling operations	Electrolysis
Organic liquids	Petrochemicals/mixed alcohol	Distillation
Inorganic aqueous solution	Concentration of inorganic salts/acids	Evaporation
Separate phase solids, grease/oil	Tannery waste/petroleum waste	Sedimentation/skimming
Chrome salt solutions	Chromium-plating solutions/tanning solutions	Reduction
Metals; phosphate sulfates	Steel-pickling operations	Precipitation

SOURCE: Office of Technology Assessment.

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*For a discussion of the problems being encountered with using waste exchanges for hazardous waste see "Industrial Waste Exchange: A Mechanism for Saving Energy and Money," Argonne National Laboratory, July 1982.

gories. **Physical separation** includes gravity settling, filtration, flotation, flocculation, and centrifugation. These operations take advantage of differences in particle size and density. **Component separation** technologies distinguish constituents by differences in electrical charge, boiling point, or miscibility. Examples include ion exchange, reverse osmosis, electrolysis, adsorption, evaporation, distillation, and solvent extraction. **Chemical transformation** requires chemical reactions to remove specific chemical constituents. Examples include precipitation, electrodialysis, and oxidation-reduction reactions. These technologies are reviewed in table 27.

A typical recovery and recycling system usually uses several technologies in series. Therefore, what may appear as a complex process actually is a combination of simple operations. For example, recylcing steel-pickling liquors may involve precipitation, gravity settling, and flotation. Precipitation transforms a component of high solubility to an insoluble substance that is more easily separated by gravity settling, a coarse separation technique, and flotation, a finishing separation method. Integration of process equipment can introduce some complexity. The auxiliary handling equipment (e.g., piping, pumps, controls, and monitoring devices that are required to provide continuous treatment from one phase to another) can be extensive. A detailed description of the recycling and recovery of pickling liquors from the steel industry is provided in the appendix at the end of this chapter.

Recovery and recycling technologies applied to waste vary in their stages of development. Physical separation techniques are the most commonly used and least expensive. The separation efficiency of these techniques is not as high as more complex systems, and therefore the type of waste to which it is applied is limited. Complex component separations (e.g., reverse osmosis) are being investigated for application to hazardous waste. These generally are expensive operations and have not been implemented commercially for hazardous waste reduction. Chemical transformation methods are also expensive. Precipitation and thermal oxidation, however, appear to have current commercial application in hazardous waste management.

Table 28 illustrates some technologies currently being investigated for application to waste recovery and recycle. An expanded discussion of emerging new technologies, specifically in phase separation is provided in the following section of this chapter.

Economic Factors

These factors include:

1. research and development required prior to implementation of a technology;
2. capital investment required for new raw material, or additional equipment; i.e., recovery and recycle equipment, control equipment, and additional instrumentation;
3. energy requirements and the potential for energy recovery;
4. improvements in process efficiency;
5. market potential for recycled material, either in-house or commercially, and anticipated revenues;
6. management costs for hazardous waste before use of recovery and recycle technology;
7. waste management cost increases, resulting from recovery/recycling, i.e., additional manpower, insurance needs, and potential liability; and
8. the value of improved public relations of a firm.

Because of the number of processing steps involved, recovery and recycling can be more expensive than treatment and disposal methods. Earned revenue for recovered materials, however, may counter the cost of recovery.

Many market and economic uncertainties must be considered in an evaluation of proposed technology changes. For example, if deregulation of oil and natural gas results in an increase in energy costs, additional energy requirements, and/or credits earned for energy recovery from a process could be affected. The uncertainty of continued availability of a nec-

Table 27.—Description of Technologies Currently Used for Recovery of Materials

Technology/description	Stage of development	Economics	Types of waste streams	Separation efficiency[a]	Industrial applications
Physical separation:					
Gravity settling:					
Tanks, ponds provide hold-up time allowing solids to settle; grease skimmed to overflow to another vessel	Commonly used in wastewater treatment	Relatively inexpensive; dependent on particle size and settling rate	Slurries with separate phase solids, such as metal hydroxide	Limited to solids (large particles) that settle quickly (less than 2 hours)	Industrial wastewater treatment first step
Filtration:					
Collection devices such as screens, cloth, or other; liquid passes and solids are retained on porous media	Commonly used	Labor intensive: relatively inexpensive; energy required for pumping	Aqueous solutions with finely divided solids; gelatinous sludge	Good for relatively large particles	Tannery water
Flotation:					
Air bubbled through liquid to collect finely divided solids that rise to the surface with the bubbles	Commercial application	Relatively inexpensive	Aqueous solutions with finely divided solids	Good for finely divided solids	Refinery (oil/water mixtures); paper waste; mineral industry
Flocculation:					
Agent added to aggregate solids together which are easily settled	Commercial practice	Relatively inexpensive	Aqueous solutions with finely divided solids	Good for finely divided solids	Refinery; paper waste; mine industry
Centrifugation:					
Spinning of liquids and centrifugal force causes separation by different densities	Practiced commercially for small-scale systems	Competitive with filtration	Liquid/liquid or liquid/solid separation, i.e., oil/water; resins; pigments from lacquers	Fairly high (90%)	Paints
Component separation:					
Distillation:					
Successfully boiling off of materials at different temperatures (based on different boiling points)	Commercial practice	Energy intensive	Organic liquids	Very high separations achievable (99+% concentrations) of several components	Solvent separations; chemical and petroleum industry
Evaporation:					
Solvent recovery by boiling off the solvent	Commercial practice in many industries	Energy intensive	Organic/inorganic aqueous streams; slurries, sludges, i.e., caustic soda	Very high separations of single, evaporated component achievable	Rinse waters from metal-plating waste
Ion exchange:					
Waste stream passed through resin bed, ionic materials selectively removed by resins similar to resin adsorption. Ionic exchange materials must be regenerated	Not common for HW	Relatively high costs	Heavy metals aqueous solutions; cyanide removed	Fairly high	Metal-plating solutions
Ultrafiltration:					
Separation of molecules by size using membrane	Some commercial application	Relatively high	Heavy metal aqueous solutions	Fairly high	Metal-coating applications
Reverse osmosis:					
Separation of dissolved materials from liquid through a membrane	Not common: growing number of applications as secondary treatment process such as metal-plating pharmaceuticals	Relatively high	Heavy metals; organics; inorganic aqueous solutions	Good for concentrations less than 300 ppm	Not used industrially

Table 27.—Description of Technologies Currently Used for Recovery of Materials—Continued

Technology/description	Stage of development	Economics	Types of waste streams	Separation efficiency[a]	Industrial applications
Electrolysis:					
Separation of positively/negatively charged materials by application of electric current	Commercial technology; not applied to recovery of hazardous materials	Dependent on concentrations	Heavy metals; ions from aqueous solutions; copper recovery	Good	Metal plating
Carbon/resin absorption:					
Dissolved materials selectively absorbed in carbon or resins. Absorbents must be regenerated	Proven for thermal regeneration of carbon; less practical for recovery of adsorbate	Relatively costly thermal regeneration; energy intensive	Organics/inorganics from aqueous solutions with low concentrations, i.e., phenols	Good, overall effectiveness dependent on regeneration method	Phenolics
Solvent extraction:					
Solvent used to selectively dissolve solid or extract liquid from waste	Commonly used in industrial processing	Relatively high costs for solvent	Organic liquids, phenols, acids	Fairly high loss of solvent may contribute to hazardous waste problem	Recovery of dyes
Chemical transformation:					
Precipitation:					
Chemical reaction causes formation of solids which settle	Common	Relatively high costs	Lime slurries	Good	Metal-plating wastewater treatment
Electrodialysis:					
Separation based on differential rates of diffusion through membranes. Electrical current applied to enhance ionic movement	Commercial technology, not commercial for hazardous material recovery	Moderately expensive	Separation/concentration of ions from aqueous streams; application to chromium recovery	Fairly high	Separation of acids and metallic solutions
Chlorinolysis:					
Pyrolysis in atmosphere of excess chlorine	Commercially used in West Germany	Insufficient U.S. market for carbon tetrachloride	Chlorocarbon waste	Good	Carbon tetrachloride manufacturing
Reduction:					
Oxidative state of chemical changed through chemical reaction	Commercially applied to chromium; may need additional treatment	Inexpensive	Metals, mercury in dilute streams	Good	Chrome-plating solutions and tanning operations
Chemical dechlorination:					
Reagents selectively attack carbon-chlorine bonds	Common	Moderately expensive	PCB-contaminated oils	High	Transformer oils
Thermal oxidation:					
Thermal conversion of components	Extensively practiced	Relatively high	Chlorinated organic liquids; silver	Fairly high	Recovery of sulfur, HCl

[a] Good implies 50 to 80 percent efficiency, fairly high implies 80 percent, and very high implies 90 percent.

SOURCE: Office of Technology Assessment.

Table 28.—Recovery/Recycling Technologies Being Developed

Technology	Development needs	Potential application
Ion exchange	Commercial process for other applications (desalinization), applications to metal recovery under development. Not economic at present due to investment requirements	Chromium recovery; metal-plating waste
Adsorption	R&D on new resins and regeneration methods	Organic liquids with or without metal contamination; pesticides
Electrolysis	Cathode/anode, material development for membranes	Metallic/ionic solution
Extraction	Reduction in loss of acid or solvent in process	Extraction of metals with acids
Reverse osmosis	Membrane materials, operating conditions optimized, demonstration of process	Salt solutions
Evaporation	Efficiency improvement/ demonstration of process	Fluorides from aluminum smelting operation
Reduction	Efficient collection techniques	Mercury
Chemical dehalogenation	Equipment development for applications to halogenated waste other than PCB oils	Halogenated organics

SOURCE: Office of Technology Assessment.

essary raw material could influence a decision for recovery of materials from waste streams. Uncertainties in interest rates may discourage investment and could thus increase a required rate-of-return projected for a new project. Changes in allowable rates of capital equipment depreciation also may affect costs significantly.

In addition, changes in RCRA regulations for alternative management options (e.g., landfilling, ocean dumping, and deep-well injection) affect disposal costs. Stricter regulations or prohibitions of certain disposal practices for particular wastes could increase the attractiveness of recycling and recovery operations. However, if hazardous wastes are stored for longer than 90 days, current regulations require permits for that facility. If large quantities of a waste must accumulate (for economic reasons) prior to recycling or recovery, the permit requirement may discourage onsite recycling.

Previously, recovery and recycling was considered as an in-plant operation only; i.e., material was recovered and recycled within one plant. Currently, larger corporations are beginning to evaluate recovery opportunities on a broader scale. Recycling within the corporate framework is gaining greater attention as a cost reduction tool with an added benefit of reducing public health risks.

Emerging Technologies for Waste Reduction

Although the effects are more difficult to predict, some technological developments have potential for the reduction of hazardous waste. For example, developments in the electronics industry have provided instrumentation and control systems that have greater accuracy than was possible just a few years ago. These systems provide more precise control of process variables, which can result in higher efficiency and fewer system upsets, and a reduction in hazardous waste. The application and improvements of instrumentation and control systems vary with each process. Thus, as new plants are constructed and fitted with new technologies, smaller quantities of hazardous waste will be generated. The technologies that are discussed in this section have a direct impact on the volume and hazard level of waste currently generated through one or more of the reduction methods discussed earlier.

Segregation Technology.—New developments in segregation technology can increase recovery and recycling of hazardous waste. Notably, membrane segregation techniques have substantially improved. Membrane separation has been used to achieve filtration, concentration, and purification. However, large-scale applications, such as those required in pollution control have been inhibited by two factors: 1) replacement costs associated with membrane use and 2) technical difficulties inherent in producing large uniform surface areas of uniform quality. Because of the inherent advantages of membrane separation over more conventional separation techniques like distillation or evaporation, further development of membrane separation for large-scale commercial applications is attractive. These advantages include lower energy requirements resulting in reduced operating costs and a simpler, more compact system that generally leads to reduced capital costs. Commercial applications exist for all but coupled transport designs, which are still at the laboratory stage. All of these illustrated systems have possible application for reduction of hazardous waste. However, microfiltration, ultrafiltration, reverse osmosis, and electrodialysis processes have more immediate application. Dialysis has been used on only a small scale; the high flow systems generally typical of hazardous waste treatments make its use impractical. Gas separations by membranes do not have immediate application to hazardous waste use. The development of new materials for both membranes and supporting fabrics and the use of new layering techniques (e.g., composite membranes) have led to improved permeability and selectivity, higher fluxes, better stability, and a reduced need for prefiltering and staged separations.

Improved reliability is the most important factor in advancement of membrane separations technology. New types of membranes have demonstrated improved performance. Thin-film composites that can be used in reverse osmosis, coupled transport, and electrolytic membranes have direct application to the recovery and reduction of hazardous materials from a processing stream.

The major cost in a membrane separation system is the engineering and development work required to apply the system to a particular process. Equipment costs are secondary; membranes generally account for only 10 percent of system costs. However, membranes must be replaced periodically and sales of replacement membranes are important to membrane production firms. Currently the largest profit items are for high-volume flow situations (e.g., water purification) or for high-value product applications (e.g., pharmaceutical productions). Over 20 companies cover the membrane market; the largest company is Millipore with 1980 total sales of $255 million.

The predicted market growth rate for membrane segregations is healthy, generally 10 to 20 percent annually of the present membrane market ($600 million to $950 million). Chloralkali membrane electrodialysis cells for the production of chlorine and sodium hydroxide lead the projected application areas in hazardous waste with growth rates of 25 to 40 percent of the present market ($10 million to $15 million). The recovery of chromic acid from electroplating solutions by coupled transport also has direct application for the reduction of hazardous waste. Other uses include ultrafiltration of electrocoat-painting process waste and waste water recovery by reverse osmosis. The use of membrane segregation systems in pretreatment of hazardous waste probably is the largest application for the near future.

Biotechnology.—Conventional biological treatments have been used in industrial waste treatment systems for many years (see tables 29 and 30). Recent advances in the understanding of biological processes have led to the development of new biological tools, increasing the opportunities for biotechnology applications in many areas, including the treatment of dilute hazardous waste. The potential impacts of these advancements on waste treatment techniques, process modifications, and end-product substitutes are discussed here.

Biotechnology has direct application to waste treatment systems to degrade and/or detoxify

Table 29.—Conventional Biological Treatment Methods

Treatment method	Aerobic (A) anaerobic (N)	Waste applications	Limitations
Activated sludge	A	Aliphatics, aromatics, petrochemicals, steelmaking, pulp and paper industries	Volatilization of toxics; sludge disposal and stabilization required
Aerated lagoons	A	Soluble organics, pulp and paper, petrochemicals	Low efficiency due to anaerobic zones; seasonal variations; requires sludge disposal
Trickling filters	A	Suspended solids, soluble organics	Sludge disposal required
Biocontactors	A	Soluble organics	Used as secondary treatment
Packed bed reactors	A	Nitrification and soluble organics	Used as secondary treatment
Stabilization ponds	A&N	Concentrated organic waste	Inefficient; long retention times, not applicable to aromatics; sludge removal and disposal required
Anaerobic digestion	N	Nonaromatic hydrocarbons; high-solids; methane generation	Long retention times required; inefficient on aromatics
Landfarming/spreading	A	Petrochemicals, refinery waste, sludge	Leaching and runoff occur; seasonal fluctuations; requires long retention times
Composting	A	Sludges	Volatilization of gases, leaching, runoff occur; long retention time; disposal of residuals

Aerobic—requires presence of oxygen for cell growth
Anaerobic—requires absence of oxygen for cell growth

SOURCE: Office of Technology Assessment.

Table 30.—Industries With Experience in Applying Biotechnology to Waste Management

Industry	Effluent stream	Major contaminants
Steel	Coke-oven gas scrubbing operation	NH_3, sulfides, cyanides, phenols
Petroleum refining	Primary distillation process	Sludges containing hydrocarbons
Organic chemical manufacture	Intermediate organic chemicals and byproducts	Phenols, halogenated hydrocarbons, polymers, tars, cyanide, sulfated hydrocarbons, ammonium compounds
Pharmaceutical manufacture	Recovery and purification solvent streams	Alcohols, ketones, benzene, xylene, toluene, organic residues
Pulp and paper	Washing operations	Phenols, organic sulfur compounds, oils, lignins, cellulose
Textile	Wash waters, deep discharges	Dyes, surfactants, solvents

SOURCE: Office of Technology Assessment.

chemicals. Development of new microbial strains can be used to improve:

1. degradation of recalcitrant compounds,
2. tolerance of severe or frequently changing operating conditions,
3. multicompound destruction,
4. rates of degradation, and
5. ability to concentrate nondegradable constituents.

Compounds thought to be recalcitrant, (e.g., toluene, benzene, and halogenated compounds) have been shown to be biodegradable by isolated strains. Strain improvement in these species through genetic manipulations has lead to improved degradation rates. Opportunities exist for applications of this technology in remedial situations—i.e., cleanup at spills or abandoned sites.[6] [7] The improvement of conventional biological systems through the development of specific microbial strains ("superbugs") capable of degrading multiple compounds has been proposed. However, this approach faces engineering difficulties, and development of collections of organisms working together might be preferable.

Development of **biological pretreatment systems** for waste streams has some potential for those wastes that contain one or two recalcitrant compounds. A pretreatment system designed to remove a specific toxic compound could reduce the shock effects on a conventional treatment process. In some cases, a pretreatment system may be used with other nonbiological treatment methods (i.e., incineration) to remove toxic compounds that may not be handled in the primary treatment system or to make them more readily treated by the primary system. In other cases, pretreatment might render a waste nonhazardous altogether.

One area of research in advanced plant genetics is in the use of plants to accumulate metals and toxic compounds from contaminated soils. Current research is direct to four areas. The first involves use of plants to decrease the metal content of contaminated soils, through increased rates of metal uptake. Plants then could be used to decontaminate soils through concentration of compounds in the plant fiber. The plants then would be harvested and disposed. The second area of development focuses on direct metal uptake in nonedible portions of the plant. For example, the development of a grain crop like wheat that could accumulate metal from soil in the nonusable parts of the plant would allow commercial use of contaminated land. A third area of research is directed toward development of crops that can tolerate the presence of metal without incorporating these toxic elements in plant tissue. Finally, research is being conducted concerning the use of plants in a manner similar to microorganisms to degrade high concentrations of hazardous constituents.

Changes in process design incorporating advances in biological treatment systems may result in less hazardous waste. The development of organisms capable of degrading specific recalcitrant materials may encourage source separation, treatment, and recycling of process streams that are now mixed with other waste streams and disposed. The replacement of chemical synthesis processes with biological processes may result in the reduction of hazardous waste. Two methods of increasing the rate of chemical reactions are through higher temperatures and catalysts. One type of catalyst is biological products (enzymes) that inherently require milder, less toxic conditions than do other catalytic materials.

Historically, many biological processes (fermentations) have been replaced by chemical synthesis. Genetic engineering offers opportunities to improve biological process through reduced side reactions, higher product concentrations, and more direct routes; thus, genetic engineering offers a means of partially reversing this trend. The development of new process approaches would require new reactor designs to take advantage of higher biological reaction rates and concentrations.

Biotechnology also could lead to substitution of a less or nonhazardous material for a hazardous material, particularly in the agricultural field. One of the primary thrusts of plant genetics is the development of disease-resistant plants, thus reducing the need for commercial products such as fungicides. Genetic engineering to introduce nitrogen-fixation capabilities within plants could reduce the use of chemical fertilizers and potentially reduce hazardous waste generated in the manufacture of those chemicals. However, two problems must be resolved before large-scale applications: 1) the genetic engineering involved in nitrogen fixation is complex and not readily achieved, and 2) the overall energy balance of internal nitrogen-fixation may reduce growth rates and crop yield.

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[6] G. T. Thibault and N. W. Elliott, "Biological Detoxification of Hazardous Organic Chemical Spills," in *Control of Hazardous Material Spills*, Conference Proceedings (Nashville, Tenn.: Vanderbilt University, 1980), pp. 398-402.

[7] G. C. Walton and D. Dobbs, "Biodegradation of Hazardous Materials in Spill Situations," in *Control of Hazardous Material Spills*, Conference Proceedings (Nashville, Tenn.: Vanderbilt University, 1980), pp. 23-45.

Major Concerns for Biotechnology.—Although genetic engineering has some promising applications in the treatment of hazardous waste streams, several issues need to be addressed prior to widespread commercialization of the technology:[8]

- The factors for scale-up from laboratory tests to industrial applications have not been completely developed. Limited field tests have shown degradation rates in the field may be much slower than laboratory rates where pure cultures are tested in pure compounds.
- Basic biochemical degradation mechanisms are not well understood. The potential exists for the formation of other hazardous compounds through small environmental changes or system upsets and, without this basic understanding, chemical pathways cannot be anticipated.
- The potential exists for release of hazardous compounds into the environment through incomplete degradation or system failure.
- There is a possibility of adverse effects resulting from the release of "engineered" organisms into the environment.

The potential benefits of applied genetics to hazardous waste probably outweigh these factors. Although these factors must be addressed, they should motivate rather than overshadow research in this area.

Chemical Dechlorination With Resource Recovery.—In the late 1970's private efforts were undertaken to find a reagent that would selectively attack the carbon-chlorine bond under mild conditions, and thus chemically strip chlorine from PCB-type chemicals forming a salt and an inert sludge. Goodyear Tire & Rubber Co. made public its method. Sunohio and Acurex Inc. have developed proprietary reagents, modified the process, and commercialized their processes with mobile units. These processes reduce the concentration of PCB in transformer oil, which may be 50 to 5,000 parts per million (ppm) to less than 2 ppm. The Sunohio PCBX process is used for direct recycling of the transformer oil back into transformers, while the oil from the Acurex process is used as a clean fuel in boilers.[9]

Although, the development of these processes was initially aimed at PCB-laden oils of moderate concentration (50 to 500 ppm), their chemistry is generic in that it attacks the carbon-halogen bonds under mild conditions. Thus, they are potentially applicable to pesticides and other halogenated organic wastes as well as wastes with higher concentrations of PCBs. The PCBX process has been applied to pesticides and other halogenated waste with detoxification observed, but without published numerical results or further developments.[10] Acurex claims it has commercially treated oil with a PCB concentration of 7,000 ppm. In tests performed by Battelle Columbus Laboratories for Acurex, its process reduced dioxin concentration in transformer oil from 380 parts per trillion (ppt) to 40 ± 20 ppt. Acurex and the Energy Power Research Institute have tested the effectiveness of the process in the laboratory on capacitors which contain 100 percent PCB (40 to 50 percent chlorine, by weight). The next step is construction of a mobile commercial-scale facility which would shred, batch process, and test the capacitor material.[11]

The Sunohio (first to have a chemical dechlorination process approved by EPA) has five units in operation. Acurex has four mobile units in operation at this time and at least two other companies currently market similar chemical PCB destruction services. Acurex,

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[8] S. P. Pirages, L. M. Curran, and J. S. Hirschhorn, "Biotechnology in Hazardous Waste Management: Major Issues," paper presented at *The Impact of Applied Genetics on Pollution Control*, symposium sponsored by the University of Notre Dame and Hooker Chemical Co., South Bend, Ind., May 24-26, 1982.

[9] *Alternatives to the Land Disposal of Hazardous Wastes*, Governor's Office of Appropriate Technology, California, 1981.

[10] Oscar Norman, developer of the PCBX process, personal communication, January 1983.

[11] Leo Weitzman, Acurex Corp., personal communication, January 1983.

Sunohio, and licensees have been selling their PCB services for over a year. Acurex and The Franklin Institute plan to commercialize their processes for spill sites involving halogenated organics.[12]

As an alternative to incineration, these chemical processes offer the advantages of no air emissions, no products of incomplete combustion, reduced transportation risks, and the recycling of a valuable material or the recovery of its fuel value. Further, as with many chemical processes, there is the opportunity to directly check the degree of destruction before any product is discharged or used.

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[12] Charles Rogers, Office of Research and Development, Industrial and Environmental Research Laboratory (IERL), Environmental Protection Agency, Cincinnati, Ohio, personal, communication, January 1983.

Hazard Reduction Alternatives: Treatment and Disposal

Introduction

The previous section discussed technologies to reduce the volume of waste generated. This section analyzes technologies that reduce the hazard of waste. These include treatment and **disposal technologies. These two groupings of technologies contrast distinctly in that it is preferable to permanently reduce risks to human health and the environment by waste treatments that destroy or permanently reduce the hazardous character of the material, than to rely on long-term containment in land-based disposal structures.**

In the United States, as much as 80 percent (by volume) of the hazardous waste generated is land disposed (see ch. 4). Of these wastes, a significant portion could be treated rather than land disposed for greater hazard reduction. In California, for example, wastes which are toxic, mobile, persistent and bioaccumulative comprise about 29 percent of the hazardous waste disposed of offsite.[13] [14]

Following a brief summary comparison, this section reviews over 15 treatment technologies. Many of these eliminate the hazardous character of the waste. Technologies in the next group discussed are disposal alternatives. Their effectiveness relies on containing the waste to prevent, or to minimize, releases of waste and human and environmental exposure to waste. In this category, the major techniques are landfills, surface impoundments, and underground injection wells.

This discussion begins with a comparison of the treatment and disposal technologies and ends with a cost comparison. These discussions focus on the competitive aspects of the numerous hazard reduction technologies. However, choosing among these technical alternatives involves consideration of many factors, some of which are neither strictly technical or economic. Choices by waste generators and facility operators also depend on Federal and State regulatory programs already in place, those planned for the future, and on perceptions by firms and individuals of existing regulatory burdens may exist for a specific waste, technology, and location.

Summary Comparison

For the purpose of an overview, qualitative comparisons among technologies can be made. Based on principle considerations relevant across all technologies, the diverse range of hazard reduction technologies can be compared as presented in table 31. The table summarizes the important aspects of the above issues for each generic grouping of technologies included. Individual technologies are considered in more detail in the following discussions on treatment and disposal technologies. For simplicity, the technologies are grouped generically, and only a limited number

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[13] California Department of Health Services, "Initial Statement of Reasons for Proposed Regulations (R-32-82)," Aug. 16, 1982, p. 23.

[14] California Department of Health Services, "Current Hazardous Waste Generation," Aug. 31, 1982, p. 6.

Table 31.—Comparison of Some Hazard Reduction Technologies

	Disposal		Treatment		
	Landfills and impoundments	Injection wells	Incineration and other thermal destruction	Emerging high-temperature decomposition[a]	Chemical stabilization
Effectiveness: How well it contains or destroys hazardous characteristics	Low for volatiles, questionable for liquids; based on lab and field tests	High, based on theory, but limited field data available	High, based on field tests, except little data on specific constituents	Very high, commercial-scale tests	High for many metals, based on lab tests
Reliability issues.	Siting, construction, and operation Uncertainities: long-term integrity of cells and cover, liner life less than life of toxic waste	Site history and geology; well depth, construction and operation	Long experience with design Monitoring uncertainties with respect to high degree of DRE; surrogate measures, PICs, incinerability	Limited experience Mobile units; onsite treatment avoids hauling risks Operational simplicity	Some inorganics still soluble Uncertain leachate test, surrogate for weathering
Environmental media most affected:	Surface and ground water	Surface and ground water	Air	Air	None likely
Least compatible waste:[b]	Liner reactive; highly toxic, mobile, persistent, and bioaccumulative	Reactive; corrosive; highly toxic, mobile, and persistent	Highly toxic and refractory organics, high heavy metals concentration	Possibly none	Organics
Costs: Low, Mod, High	L-M	L	M-H (Coincin. = L)	M-H	M
Resource recovery: potential	None	None	Energy and some acids	Energy and some metals	Possible building material

[a] Molten salt, high-temperature fluid wall, and plasma arc treatments.

[b] Waste for which this method may be less effective for reducing exposure, relative to other technologies. Waste listed do not necessarily denote common usage.

SOURCE: Office of Technology Assessment.

of groups are compared. The principal considerations used for comparison are the following:

- **Effectiveness.**—This does not refer to the intended end result of human health and environmental protection, but to the capability of a technology to meet its specific technical objective. For example, the effectiveness of chemical dechlorination is determined by how completely chlorine is removed. In contrast, the effectiveness of landfills is determined by the extent to which containment or isolation is achieved.
- **Reliability.**—This is the consistency over time with which a technology's objective is met. Evaluation of reliability requires consideration of available data based on theory, laboratory-scale studies, and commercial experience.

A prominent factor affecting the relative reliability of a technology is the adequacy of **substitute performance measures.** Verification that a process is performing as designed is not always possible and, when possible, verification to a high level of confidence may require days or weeks to complete and may not be useful for timely adjustments. In some cases, key process variables can be used as substitute measures for the effectiveness of the technology. Substitute measures are used either because they provide faster and/or cheaper performance information. A disadvantage of surrogate measures is that there may not be reliable correlation between the surrogate measurement and the nature of any releases to the environment.

The reliability of a technology should also be judged on the **degree of process and discharge control available.** This refers to the ability to: 1) maintain proper operating conditions for the process, and 2) correct undesirable releases. Process control requires that information about performance be fed back to correct the process. Control systems vary categorically with respect to two important time variables:

1. the length of time required for information to be fed back into the system (e.g., time for surrogate sampling and analysis, plus time for corrective adjustments to have the desired effect); and
2. the length of time for release of damaging amounts of insufficiently treated materials in the event of a treatment upset.

In the case of landfills, once ground water monitoring has detected a leak, damaging discharges could have already occurred.

If detection systems are embedded in the liner, then detection of a system failure is quicker and more reliable, and it offers more opportunity for correction. Landfilling and incineration are examples where these time factors are important. In contrast, batch treatment processes, as discussed in the preceding section on "Waste Reduction," offer the distinct opportunity to contain and check any release, and retreat it if needed, so that actual releases of hazardous constituents are prevented. Other chemical and biological treatments are flow-through processes, with different rates of flow-through. These treatments vary in their opportunity for discharge correction. Generally, processes used in waste segregration and recycling offer this kind of reliability.

- **Environmental media most affected.**—This refers to the environmental media contaminated in the event that the technology fails.
- **Least compatible waste.**—Some technologies are more effective than others in preventing releases of hazardous constituents when applied to particular types of waste.
- **Costs.**—Costs vary more widely among generic groups of technologies than within these groups. Table 31 presents generalized relative costs among these groups. The final section of this chapter gives some unit management cost details.
- **Resource recovery potential.**—Treatments that detoxify and recover materials for recycling are discussed under "Waste Reduction." However, some materials, as well as energy, can be recovered with some of the technologies reviewed in this section. To the extent that materials and fuels are recovered and used, the generation of other hazardous wastes may be reduced. Potential releases of hazardous constituents from recovery and recycling operations must also be considered.

Treatment Technologies

In this section, treatment technologies refers to those techniques which decompose or break down the hazardous wastes into nonhazardous constituents.* Most of these treatments use high temperatures to decompose waste. Some of the promising emerging technologies cause decomposition by high-energy radiation and/or electron bombardment. There are several important attributes of high-temperature destruction technologies which make them attractive for hazardous waste management:

- the hazard reduction achieved is **permanent;**
- they are **broadly applicable to waste mixes;** most organics, for example, may be converted into nonhazardous combustion products; and
- the **volume** of waste that must ultimately be land disposed is greatly **reduced**.

In addition, with some of these treatments, there is a possibility of recovering energy and/or materials.** However, potential recovery of energy and materials is not the primary focus of this discussion.

Incineration is the predominant treatment technology used to decompose waste. The term "incineration" has been given a specific meaning in Federal regulations, where it denotes a particular subclass of thermal treatments, and draft Federal regulations may give specific meaning to the additional terms "industrial boiler" and "industrial furnace." Although the Federal definitions affect the manner in which a facility is regulated, unless specifically noted,

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*Treatments can also be used to **segregate** specific waste constituents, or to **mitigate** their characteristics of ignitability, corrosiveness, or reactivity. Most of these are referred to as "industrial unit processes," and their use is usually embedded in larger treatment schemes. A lengthy listing will not be reproduced here. Many were described in the preceding section on "Waste Reduction Technologies." The interested reader is also referred to any industrial unit operations manual. Another source is "Chemical, Physical, Biological (CPB) Treatment of Hazardous Wastes," Edward J. Martin, Timothy Oppelt, and Benjamin Smith, Office of Solid Waste, U.S. Environmental Protection Agency, presented at the Fifth United States-Japan Governmental Conference of Solid Waste Management, Tokyo, Japan, Sept. 28, 1982.

**For example, the Chemical Manufacturers Association claims that a significant portion of the hydrochloric acid produced in the United States and some sulfuric acid come from incineration of chlorinated organics through wet-scrubbing of the stack gases. (CMA, personal communication, December 1982.) Also, there is clear potential for metals recovery with the emerging high-temperature technologies.

"combustion" or "incineration" are used in this report to refer to the generic processes of interest, and do not necessarily mean specific facility designs or regulatory categories.

Applicable Wastes

Liquid wastes are generally more easily incinerated than sludge or waste in granular form, because they can be injected easily into the combustion chamber in a manner which enhances mixing and turbulence. Wastes with heterogeneous physical characteristics and containerized or drummed wastes are difficult to feed into a combustion chamber. The rotary kiln is designed for sludge-like, granular and some containerized waste. Recently, a new firm has emerged (Continental Fibre Drum) which manufactures combustible fiber drums for waste containers. These fiber drums of organic waste can be incinerated in specially designed rotary kilns.

Elemental metals, of course, cannot be degraded. Waste which contain excessive levels of volatile metals may not be suitable for incineration. Under the high-temperature conditions in an incinerator, some metals are volatilized or carried out on particulates. Oxides of metals can generally be collected electrostatically. However, some volatilized forms cannot be electrically charged, resisting electrostatical collection. These include metallic mercury, arsenic, antimony, and cadmium, and very small particles.[15] (Particles having insufficient surface area also can't be adequately charged and collected.) Wet second-stage electrostatic precipitators are designed for removing these forms of volatized metals, but they are expensive and not in widespread use. High-pressure drop-emission controllers have also been effective, but their use is declining.

Technical Issues

There are approximately 350 liquid injection and rotary kiln incinerators currently in service for hazardous waste destruction.[16] Most of these facilities may eventually be permitted as RCRA hazardous waste incinerators. A far greater, although unknown, number of facilities may be combusting hazardous waste principally in order to recover their heating value. Under current regulations, these facilities would not be permitted as hazardous waste incinerators.[17] Under future regulations they may become subject to performance standards similar to those in effect for incinerators, be prohibited from burning certain types of ignitable hazardous waste, or be subject to some intermediate level of regulation.

To regulate incinerators, EPA has decided to use **performance standards** rather than specification of design standards. The current regulations specify three performance standards for hazardous waste incineration.[18] These standards are described below:

1. A 99.99 percent destruction and removal efficiency (DRE) standard for each principal organic hazardous constituent (POHC) designated in the waste feed. (This is the most difficult part of the standard to meet.) The DRE is calculated by the following mass balance formula:

   $DRE = (1 - Wout/Win) \times 100$ percent,
   where:
   Win = the mass feed rate of 1 POHC in the waste stream going into the incinerator, and
   Wout = the mass-emission rate of the same POHC in the exhaust prior to release to the atmosphere.
2. Incinerators that emit more than 4 lb of hydrogen chloride per hour must achieve a removal efficiency of at least 99 percent. (All commercial scrubbers tested by EPA have met this performance requirement.)
3. Incinerators cannot emit more than 180 milligrams (mg) of particulate matter per dry standard cubic meter of stack gas. This standard is intended to control the emissions of metals carried out in the exhaust gas on particulate matter. (Recent tests indicate that this standard may be more difficult to achieve than was earlier thought.[19])

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[15] Frank Whitmore, Versar, Inc., personal communication, August 1982.

[16] Gene Crumpler, Office of Solid Waste, Hazardous and Industrial Waste Division, Environmental Protection Agency, personal communication, January 1983.

[17] Ibid.

[18] 40 CFR, sec. 264.343.

[19] Crumpler, op. cit.

There are instances in which the incinerator performance standards do not fully apply. First the regulations do not apply to facilities that burn waste primarily for its fuel value. To date, energy recovery of the heat value of waste streams qualifies for the regulatory exemption.[30] Second, facilities burning waste that are considered hazardous because of characteristics of ignitability, corrosiveness, and reactivity are eligible for exemptions from the performance standards. Of the three, the exemption for energy recovery applies to a greater volume of hazardous waste. Finally, incinerators operating at sea are not governed by RCRA, but rather by the Marine Protection, Research, and Sanctuaries Act of 1972. Regulations under this act do not require scrubbing of the incinerator exhaust gas. In the future, EPA may require that incinerator ships operating in close proximity to each other scrub their exhaust gases.

With regard to combustion processes, the most important design characteristics are the "three Ts:"

1. maintenance of adequate **temperatures** within the chamber,
2. adequate **turbulence** (mixing) of waste feed and fuel with oxygen to assure even and complete combustion, and
3. adequate residence **times** in the high-temperature zones to allow volatilization of the waste materials and reaction to completion of these gases.

Finally, the DRE capability of these technologies generally varies widely depending on the waste type to which it is applied. Chlorine or other halogens in the waste tend to extinguish combustion; so, in general, these wastes tend to be more difficult to destroy. An important related misconception is that the more toxic compounds are the more difficult they are to burn. Toxic dioxins and PCBs are popular examples of highly halogenated wastes which are both highly toxic and difficult to destroy, but these should not imply a rule. Discussion of waste "incinerability" is included below.

Waste treatments with reliable high-destruction efficiencies offer attractive alternatives to land disposal for mobile, toxic, persistent, and bioaccumulative wastes. However, these treatment technologies are not free of technical issues. The first three issues noted below relate directly to **policy** and regulation, and the remaining three issues summarize sources of technical **uncertainty** with respect to the very small concentrations of remaining substances. Improvements in policy and regulatory control should recognize these technical issues:

- **Significant sources of toxic combustion products, emitted to the air, are not being controlled with the same rigor as are RCRA incinerators.** These include emissions from facilities inside the property boundaries of refineries and other chemical processing plant sites. In addition, "boilers" can receive and burn any ignitable hazardous waste which has beneficial fuel value (see discussion on "Boilers"). Draft regulations governing boilers are currently being developed under RCRA and very limited reporting requirements are brand new. Under the Clean Air Act, there is only very limited implementation governing the remaining facilities. Standards have been set for only four substances, and apply to only a small class of facilities.
- **There are some problems with the technology-based DRE performance standards.** EPA uses the technology-based performance standard for **practicality,** and for its **technology-forcing** potential. However, the performance standard overly simplifies the environmental comparisons among alternatives.

  Complete knowledge about the transport, fate, and toxic effects of each waste compound from each facility is unobtainable. Thus, some simplified regulatory tool is needed. However, the most important and known factors should be included in regulatory decisions. Notably, these could include: the **toxicity** of the waste, the load to the facility (the waste feed **concentra-**

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[30] 40 CFR, sec. 261.2 (c)(2).

tion and **size** of the facility), and **population** potentially affected. Future regulations, however, could endeavor to shape the manner in which competing technologies are chosen in a more environmentally meaningful way (see ch. 6).

Finally, the 99.99 percent DRE may be viewed as a "forcing" standard with respect to some high-temperature technologies, but emerging high-temperature technologies (notably plasma arc) may offer much greater and more reliable DREs. Rather than forcing, it may discourage the wide use of more capable technologies.

- **Strengthening regulations with respect to the technical uncertainties below will require deliberate research efforts in addition to anticipated permitting tests.** Test data for wastes that are difficult to burn are lacking. The current incinerator performance standard is based on EPA surveys from the mid-1970's which involved easier to burn wastes, higher fuel to waste feed ratios than in current use, and smaller than commercial-scale reactors. EPA is currently testing or observing test burns for many of the technologies described, using compounds found to be representative of very difficult to burn toxic waste. Most of these data are still being evaluated; few results have become available. In the next few years, a great deal of test burn data will be generated regarding existing facilities and given wastes. In addition, the cost of test burn is often $20,000 to $50,000. These costs burden both EPA research and private industry. Such data will help permit writers, but these data will have limited use in resolving many of the technical uncertainties described below.
- **Implementation of the current performance standards relies on industrywide use of monitoring technology operating at the limits of its capability.** In DRE analyses, the fourth nine is often referred to as guesswork; standardized stack gas sampling protocols for organic hazardous constituents are still being developed. This is particularly true with respect to organics carried on particulate matter and to the more volatile compounds. Methods for concentrating the exhaust gas in order to obtain the sample especially for volatile compounds are still evolving. The newness of these tests suggests there may be a wide variety in the precision capabilities among the laboratories which analyze DRE test results.
- **The measurements currently used in daily monitoring of performance cannot reliably represent DRE at the 99.99 percent level.** For recordkeeping and enforcement, air and waste feed rates along with gas temperature are used as indirect measures for DRE. For facilities already equipped with carbon monoxide meters (and for all Phase II regulated incinerators), carbon monoxide concentration in the stack gas is also included. Also, waste/fuel mix and waste/fuel ratio can have a great effect on DRE. Thus, these ratios are noted in the permits. However, it is difficult to specify acceptable ranges of mixes based on test burn information. The idea behind the specifications is that as long as actual values of these parameters remain within prescribed limits during operation, the desired DRE is being achieved. These measures are chosen not only because they are easily and routinely monitored, but also because there is a theoretical basis for using them to indicate combustion efficiency. However, all these measures are only indirectly related to the compounds of concern. For example, carbon monoxide is a very stable and easily monitored product of incomplete combustion (PIC). Thus, it is often used as a sensitive indicator for combustion efficiency in energy applications. However, its relationship to other combustion products and to remaining concentrations of POHCs is very indirect and uncertain.

Most experts agree that the development of a way to accurately measure DRE **concurrently** with treatment process, would eliminate much of the technical uncertainties surrounding incineration. To this end, EPA is studying devices which monitor total organic carbon, and the National

Bureau of Standards (NBS) is studying various combinations of available monitoring techniques.[21] It is not likely that a single technique can be developed in the near term to monitor the whole range of compounds of concern, but the development of a combination of devices to do the job holds promise. However, these techniques will still have problems. This will include: cost; some reliance on correlations to surrogate measures; and, in the case of the NBS approach, the possible introduction of corrosive tracer compounds.

- **There is sharp disagreement in the scientific and regulatory community about the use of waste "incinerability."** This concept is a regulatory creation, not a physical attribute of any material. The idea behind incinerability is that as long as the least incinerable waste (i.e., the most difficult to burn waste) is destroyed to the required extent, all other waste would be destroyed to an even greater extent. Thus, waste "incinerability," in addition to waste concentration, is used to select a limited number of waste constituents for monitoring in a **test burn.** Problems with this approach result largely from lack of basic information about measures for incinerability. This presents uncertainty in the selection of those POHCs to be monitored in the waste feed and stack gas. Heat combustion is the informational surrogate currently used because it is readily determined. However, this measure relates poorly to waste incinerability. Chlorine and other halogens in the waste tend to extinguish combustion, but simple halogen content give poor indication of incinerability. Autoignition temperature is closely related to incinerability, but for most hazardous compounds, it has not been measured. Better predictors of incinerability could be developed. One scheme, proposed by NBS, would use a combination of factors, but it needs to be tested.
- **There is a lack of basic understanding about how stable toxic PICs are formed.** Some compounds, known to be very difficult to incinerate, also occur as PICs from combusting mixtures of compounds thought to be more easily burned. Our ability to monitor these compounds has only recently made such observations possible, and there are many high-temperature kinetic reactions not fully understood. Unless specifically analyzed, a selected PIC would go undetected. While additional testing of individual combustion facilities will demonstrate specific DRE capabilities, these observations are not likely to improve our fundamental understanding of PIC formation. In particular, with the cost of test burns with POHC monitoring so high, some more basic research on PIC formation would be appropriate. Current EPA research and development, however, is focused in support of near-term permitting activities.

Review of Selected High-Temperature Treatment Technologies

There are a variety of treatment technologies involving high temperatures which have, or will likely have, important roles in hazardous waste management. Most of these technologies involve combustion, but some are more accurately described as destruction by infrared or ultraviolet radiation.

Discussion below focuses on the distinguishing principles, the reliability and effectiveness, and the current and projected use of these technologies. Unless otherwise noted, DRE values were measured in accordance with EPA testing procedures. Table 32 summarizes the advantages, disadvantages, and status of these technologies.

1. **Liquid injection incineration.**—With liquid injection, freely flowing wastes are atomized by passage through a carefully designed nozzle (see fig. 8). It is important that the droplets are small enough to allow the waste to completely vaporize and go through all the subsequent stages of combustion **while** they reside in the high-temperature zones of the incinerator. Residence times in such incinerators are short, so nozzles especially, as well as other

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[21] W. Schaub, National Bureau of Standards, personal communication, January 1983.

Table 32.—Comparison of Thermal Treatment Technologies for Hazard Reduction

Advantages of design features	Disadvantages of design features	Status for hazardous waste treatment
Currently available incinerator designs:		
Liquid injection incineration:		
Can be designed to burn a wide range of pumpable waste. Often used in conjunction with other incinerator systems as a secondary afterburner for combustion of volatilized constituents. Hot refractory minimizes cool boundary layer at walls. HCl recovery possible.	Limited to destruction of pumpable waste (viscosity of less than 10,000 SSI). Usually designed to burn specific waste streams. Smaller units sometimes have problems with clogging of injection nozzle.	Estimated that 219 liquid injection incinerators are in service, making this the most widely used incinerator design.
Rotary kilns:		
Can accommodate great variety of waste feeds: solids, sludges, liquids, some bulk waste contained in fiber drums. Rotation of combustion chamber enhances mixing of waste by exposing fresh surfaces for oxidation.	Rotary kilns are expensive. Economy of scale means regional locations, thus, waste must be hauled, increasing spill risks.	Estimated that 42 rotary kilns are in service under interim status. Rotary kiln design is often centerpiece of integrated commercial treatment facilities. First noninterim RCRA permit for a rotary kiln incinerator (IT Corp.) is currently under review.
Cement kilns:		
Attractive for destruction of harder-to-burn waste, due to very high residence times, good mixing, and high temperatures. Alkaline environment neutralizes chlorine.	Burning of chlorinated waste limited by operating requirements, and appears to increase particulate generation. Could require retrofitting of pollution control equipment and of instrumentation for monitoring to bring existing facilities to comparable level. Ash may be hazardous residual.	Cement kilns are currently in use for waste destruction, but exact number is unknown. National kiln capacity is estimated at 41.5 million tonnes/yr. Currently mostly nonhalogenated solvents are burned.
Boilers (usually a liquid injection design):		
Energy value recovery, fuel conservation. Availability on sites of waste generators reduces spill risks during hauling.	Cool gas layer at walls result from heat removal. This constrains design to high-efficiency combustion within the flame zone. Nozzle maintenance and waste feed stability can be critical. Where HCl is recovered, high temperatures must be avoided. (High temperatures are good for DRE.) Metal parts corrode where halogenated waste are burned.	Boilers are currently used for waste disposal. Number of boiler facilities is unknown, quantity of wastes combusted has been roughly estimated at between 17.3 to 20 million tonnes/yr.
Applications of currently available designs:		
Multiple hearth:		
Passage of waste onto progressively hotter hearths can provide for long residence times for sludges. Design provides good fuel efficiency. Able to handle wide variety of sludges.	Tiered hearths usually have some relatively cold spots which inhibit even and complete combustion. Opportunity for some gas to short circuit and escape without adequate residence time. Not suitable for waste streams which produce fusible ash when combusted. Units have high maintenance requirements due to moving parts in high-temperature zone.	Technology is available; widely used for coal and municipal waste combustion.
Fluidized-bed incinerators:		
Turbulence of bed enhances uniform heat transfer and combustion of waste. Mass of bed is large relative to the mass of injected waste.	Limited capacity in service. Large economy of scale.	Estimated that nine fluidized-bed incinerators are in service. Catalytic bed may be developed.
At-sea incineration: shipboard (usually liquid injection incinerator):		
Minimum scrubbing of exhaust gases required by regulations on assumption that ocean water provides sufficient neutralization and dilution. This could provide economic advantages over land-based incineration methods. Also, incineration occurs away from human populations. Shipboard incinerators have greater combustion rates; e.g., 10 tonnes/hr.	Not suitable for waste that are shock sensitive, capable of spontaneous combustion, or chemically or thermally unstable, due to the extra handling and hazard of shipboard environment. Potential for accidental release of waste held in storage (capacities vary from between 4,000 to 8,000 tonnes).	Limited burns of organochlorine and PCB were conducted at sea in mid-1970. PCB test burns conducted by Chemical Waste Management, Inc., in January 1982 are under review by EPA. New ships under construction by At Sea Incineration, Inc.
At-sea incineration: oil drilling platform-based:		
Same as above, except relative stability of platform reduces some of the complexity in designing to accommodate rolling motion of the ship.	Requires development of storage facilities. Potential for accidental release of waste held in storage.	Proposal for platform incinerator currently under review by EPA.

Table 32.—Comparison of Thermal Treatment Technologies for Hazard Reduction—Continued

Advantages of design features	Disadvantages of design features	Status for hazardous waste treatment
Pyrolysis:		
Air pollution control needs minimum: air-starved combustion avoids volatilization of any inorganic compounds. These and heavy metals go into insoluble solid char. Potentially high capacity.	Greater potential for PIC formation. For some wastes produce a tar which is hard to dispose of. Potentially high fuel maintenance cost. Waste-specific designs only.	Commercially available but in limited use.
Emerging thermal treatment technologies:		
Molten salt:		
Molten salts act as catalysts and efficient heat transfer medium. Self-sustaining for some wastes. Reduces energy use and reduces maintenance costs. Units are compact; potentially portable. Minimal air pollution control needs; some combustion products, e.g., ash and acidic gases are retained in the melt.	Commercial-scale applications face potential problems with regeneration or disposal of ash-contaminated salt. Not suitable for high ash wastes. Chamber corrosion can be a problem. Avoiding reaction vessel corrosion may imply tradeoff with DRE.	Technology has been successful at pilot plant scale, and is commercially available.
High-temperature fluid wall:		
Waste is efficiently destroyed as it passes through cylinder and is exposed to radiant heat temperatures of about 4,000° F. Cylinder is electrically heated; heat is transferred to waste through inert gas blanket, which protects cylinder wall. Mobile units possible.	To date, core diameters (3", 6", and 12") and cylinder length (72") limit throughput capacity. Scale-up may be difficult due to thermal stress on core. Potentially high costs for electrical heating.	Other applications tested; e.g., coal gasification, pyrolysis of metal-bearing refuse and hexachlorobenzene. Test burns on toxic gases in December 1982.
Plasma arc:		
Very high energy radiation (at 50,000° F) breaks chemical bonds directly, without series of chemical reactions. Extreme DREs possible, with no or little chance of PICs. Simple operation, very low energy costs, mobile units planned.	Limited throughput. High use of NaOH for scrubbers.	Limited U.S. testing, but commercialization in July 1983 expected. No scale-up needed.
Wet oxidation:		
Applicable to aqueous waste too dilute for incineration and too toxic for biological treatment. Lower temperatures required, and energy released by some wastes can produce self-sustaining reaction. No air emissions.	Not applicable to highly chlorinated organics, and some wastes need further treatment.	Commercially used as pretreatment to biological wastewater treatment plant. Bench-scale studies with catalyst for nonchlorinated organics.
Super critical water:		
Applicable to chlorinated aqueous waste which are too dilute to incinerate. Takes advantage of excellent solvent properties of water above critical point for organic compounds. Injected oxygen decomposes smaller organic molecules to CO_2 and water. No air emissions.	Probable high economy of scale. Energy needs may increase on scale-up.	Bench-scale success (99.99% DRE) for DDT, PCBs, and hexachlorobenzene.

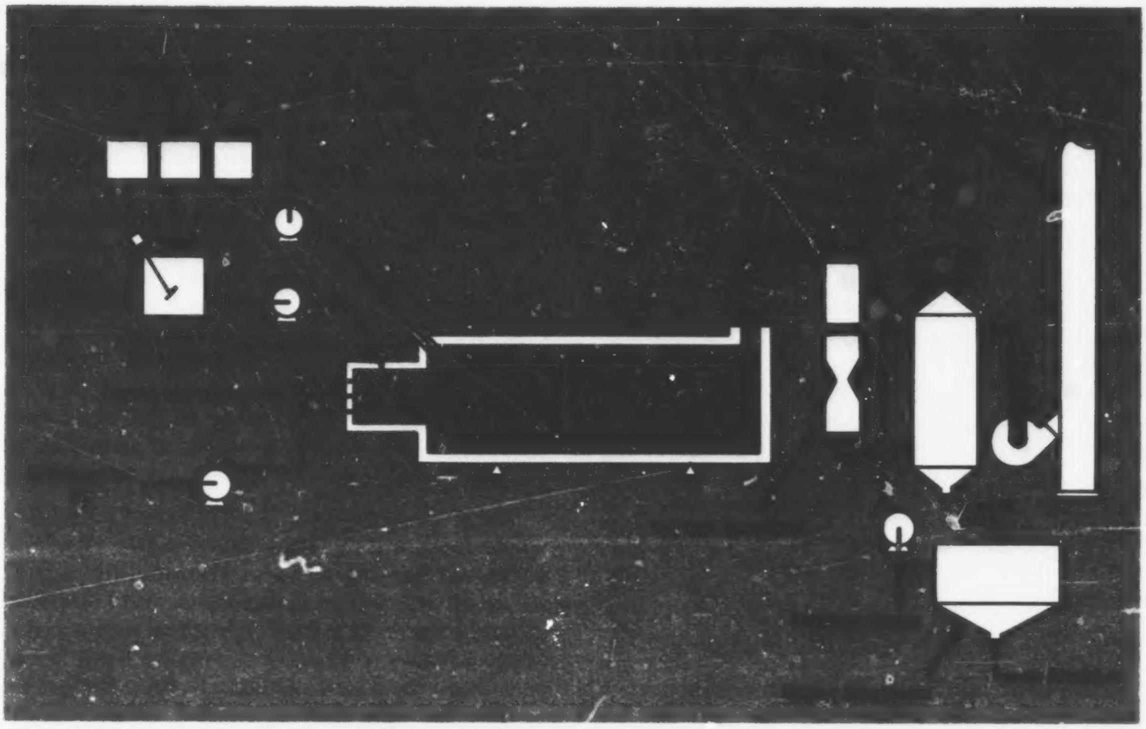
SOURCE: Office of Technology Assessment, compiled from references 12 through 29.

features, must be designed for specified waste stream characteristics such as viscosity. Certain waste must be preheated. Nonclogging nozzles are available, but all nozzles must be carefully maintained. One of the chief costs is maintenance of refractory walls. Incinerator design is a complex, but advanced field. Many distinguishing design features are currently proprietary; especially nozzle designs and refractory composition.

Injection incinerator designs, especially nozzle design, tend to be waste-specific. However, individual designs exist for the destruction of many different liquid waste mixes: motor and industrial oils, emulsions, solvents, lacquers, and organic chemicals of all kinds including relatively hard-to-destroy pesticides and chemical warfare agents.

Liquid injection incinerators, together with rotary kilns (see below) form the current basis of the hazardous waste incineration industry. These technologies have been used for the purpose of destroying industrial waste for many years. In the mid-1970's EPA testing and data reviews of these facilities provided the basis for the current interim performance standard

Figure 8.—Injection Liquid Incineration



SOURCE: D. A. Hitchcock, "Solid-Waste Disposal: Incineration," *Chemical Engineering*, May 21, 1979.

of 99.99 percent DRE for incineration of hazardous materials.

EPA has recently begun testing incinerators to better understand the DRE capabilities for the most difficult-to-burn waste. Analysis is not yet complete, but preliminary indications both confirm the 99.99 percent capabilities, and underscore the sensitivities of individual incinerators to operational and waste feed variables.[22]

2. **Rotary kilns.**—These can handle a wider physical variety of burnable waste feeds—solids and sludge, as well as free liquids and gases. A rotating cylinder tumbles and uncovers the waste, assuring uniform heat transfer. The cylinders range in size from about 3 ft in diameter by about 8 or 10 ft long, up to 15 or 20 ft in diameter by about 30 ft long. Rotary kilns operate between temperature extremes of approximately 1,500° and 3,000° F, depending on location measured along the kiln. They range in capacity from 1 to 8 tons of waste per hour.[23]

The primary advantage of rotary kilns is their ability to burn waste in any physical form and with a variety of feed mechanisms. Many large companies that use chemicals (such as Dow Chemical Co., 3M Corp., and Eastman Kodak) incinerate onsite with their own rotary kilns. For flexibility, this is often in combination with injection incinerators. Similarly, large waste management service firms (Ensco and Rollins Environmental Services) operate large rotary kilns as part of their integrated treatment centers. Others are in commercial operation throughout the United States and Europe.[24]

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[22] Timothy Oppelt, and various other personal communications, Environmental Protection Agency, Office of Research and Development, IERL, Cincinnati, Ohio, December 1982 and January 1983.

[23] Ibid.

3. **Cement kilns.**—These are a special type of rotary kiln. Liquid organic waste are cofired with the base fuel in the kiln flame. The very thorough mixing and very long residence times make possible more complete combustion of even difficult to burn organic waste. Temperatures in the kiln range between 2,600° and 3,000° F (1,400° and 1,650° C). Also, the alkaline environment in the kiln neutralizes all of the hydrochloric acid produced from the burning of chlorinated waste. Most ash and nonvolatile heavy metals are incorporated into the clinker (product of the kiln) and eventually into the cement product. Heavy metals incorporated into the clinker may present either real or perceived risks (toxicological and structural), but little is known about such concerns.[25] A portion (perhaps 10 percent) of the ash and metals carry over into the kiln dust that is collected in the system's air-pollution control system. Some of this material is recycled to the kiln, the balance is generally landfilled.[26] [27]

Five controlled test burns for chlorinated waste have been documented in wet process cement kilns in Canada, Sweden, Norway, and most recently, the United States. The foreign results have tended to confirm the theoretical predictions—that 99.99 percent or better can be achieved for chlorinated hydrocarbons. However, these studies lack strong documentation of control protocols. In the Swedish results, representative concentrations of very difficult to burn waste were destroyed beyond the limits of monitoring technology, indicating better than 99.99 percent destruction.[28] The California Air Resources Board recently recommended the use of cement kilns to destroy PCB waste.[29] EPA has recently completed a carefully controlled test on the most difficult to burn waste at the San Juan Cement Co. in Duablo, Puerto Rico. The results of this test are still being evaluated.

Some hazardous wastes are currently being burned in cement kilns under the energy recovery exclusion, but, these have been generally nonhalogenated solvents or waste oils, rather than the most toxic and/or difficult to burn compounds, for which they may be well suited. Since 1979 the General Portland Co. of Paulding, Ohio, has been burning 12,500 tons per year of nonhalogenated waste solvents as a supplemental fuel.

There is theoretically no limit on the fuel-to-waste-feed ratio; as long as the waste mix has sufficient heating value, a kiln could be fired solely on waste feed. Idled kilns could be used as hazardous waste facilities. Local public concerns, notably over spills during hauling, have presented the major obstacle to such incinerator use, but commercial interest apparently is still strong.[30] Much will depend on how new regulations affect land disposal use.

4. **Boilers.**—Ignitable waste with sufficient heating value are coincinerated with a primary fuel in some types of boilers. The boiler converts as much as possible of the heat of combustion of the fuel mix into energy used for producing steam. Different types of boilers have been designed to burn different types of fuels. Boilers burn lump coal, pulverized coal, No. 2 oil, No. 6 oil, and natural gas.[31] The predom-

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[24] *Technologies for the Treatment and Destruction of Organic Wastes as Alternatives to Land Disposal*, State of California, Air Resources Board, August 1982.

[25] Myron W. Black, "Impact of Use of Waste Fuels Upon Cement Manufacturing," paper presented at the First International Conference on Industrial and Hazardous Wastes, Toronto, Ontario, Canada, October 1982.

[26] Douglas L. Hazelwood and Francis J. Smith, et al., "Assessment of Waste Fuel Use in Cement Kilns," prepared by A. T. Kearney and the Portland Cement Association for the Office of Research and Development, EPA, contract No. 68-03-2586, March 1981.

[27] *Alternatives to the Land Disposal of Hazardous Wastes*, op. cit.

[28] Robert Olexsey, "Alternative Thermal Destruction Processes for Hazardous Wastes," Environmental Protection Agency, Office of Research and Development, May 1982.

[29] "An Air Resources Board Policy Regarding Incineration as an Acceptable Technology for PCB Disposal," State of California, Air Resources Board, December 1981.

[30] Myron W. Black, "Problems in Siting of Hazardous Waste Disposal Facilities—The Peerless Experience," paper presented at a conference on Control of Hazardous Material Spills, 1978.

[31] Environmental Protection Agency, Office of Research and Development, "Technical Overview of the Concept of Disposing of Hazardous Waste in Industrial Boilers," contract No. 68-3-2567, October 1981.

inant application to hazardous waste involves boilers of the kind that would normally burn No. 2 fuel oil.

These boilers are similar to liquid injection incinerators, but there are important differences with respect to the high destruction efficiencies desirable for hazardous waste: 1) they have purposefully cooled walls, and 2) at least some of the walls and other parts exposed to the combustion products are often metallic instead of refractory. The reason that the walls of the boiler must be cooled is to make use of the heating energy from the product gas. In the combustion chamber, this results in a relatively cool area (a thermal boundary layer) through which combustion products might pass.

The metallic surfaces avoid some expensive refractory maintenance but the bare metal surfaces are susceptible to corrosion where halogenated organic waste are burned. For this reason industrial boiler owners, concerned for the life of their equipment, probably limit their use of such waste. However, there is a growing industrial trend toward recovery of hydrochloric acid from the stack gas.* [32] Acid recovery requires that stack gas temperatures greater than 1,200° C be avoided, since this condition shifts the chemical equilibrium toward free chlorine. For hazardous waste destruction, however, higher temperatures are better.

For these reasons, efficient boilers must be designed so that hydrocarbon destruction occurs mostly **in the flame zone** with very little reaction occurring after the flame zone. As is the case with incinerators, boiler design is well advanced, and many designs are proprietary. High fuel efficiency designs may recirculate the flame envelope back into itself to enhance the formation of the series of reactions necessary for complete combustion. Other designs may involve staged injections with varying waste-to-fuel ratios.[33]

Evaluating the actual hazardous waste destruction capabilities of various boilers has only just begun by EPA. Only three tests were complete at the time of this report; seven more are planned. Tests to date have been conducted primarily with nonhalogenated, high heating value solvents and other nonhalogenated materials. These tests have demonstrated DREs generally in the 99.9 percent area. Subsequent testing will be directed toward waste that are considered to be more difficult to destroy than those tested up to this point.[34] Testing at cooperating boiler facilities is expected to confirm that boilers of a wide variety of sizes and types can achieve hazardous waste destruction efficiencies comparable to those achieved by incineration for some common waste fuels. Industry cooperation will be needed, though, for field testing of those difficult-to-burn and the more toxic wastes marginally useful as fuels.

Actual waste destruction achieved through coincineration probably has more to do with how and why the boiler is operated, and with knowledge of the waste feed contents, than with the type and size of boiler. Destruction by combustion for toxic organic compounds requires very complete, efficient combustion. Thus, in a boiler, the objective of getting usable heat out of the fuel mix is **similar** to that of achieving high destruction of toxic organic waste. **However, the marginal benefits of achieving incremental degrees of destruction may be valued differently by different users.** For example, it may cost less at very large boilers (e.g., those at utilities and large industrial facilities) to save fuel costs through increased combustion efficiency than at smaller boilers. Thus, utility boilers are probably designed and operated for stringent fuel efficiency by an economic motivation that may parallel the rigorous incinerator performance standard in its effect for DREs. Although there would be an economic advantage for these facilities to burn waste fuels, many would not be able to find reliable and sufficient supplies. On the other hand, the objective with many industrial boilers is to **deliver** an **optimal** amount of heat

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*Currently a significant amount, perhaps over 4 percent of the U.S. hydrochloric acid, is produced from stack gas scrubbers. Half of this is from boilers and half from incinerators.

[32] James Karl, Dow Chemical Co., personal communication, January 1983.

[33] Elmer Monroe, DuPont Chemical Co., personal communication, December 1982.

[34] Olexsey, op. cit.

over time. Thus, achieving 100-percent combustion efficiency is not desirable if it takes 2 days to achieve this goal. **Incinerators have as their direct goal the destruction of the fuel compound which is not so in boilers.**

Excluding the very largest utility and industrial boilers, there are about 40,000 large (10 million to 250 million Btu/hr) industrial boilers and about 800,000 small- to medium-sized institutional, commercial, and industrial boilers nationwide.[35] It is expected that most of the industrial boilers having firing capacities less than 10 million Btu/hr may not readily lend themselves to coincineration.[36]

Finally, there are about 14 million residential, single-home boilers which could burn hazardous waste.[37] These small boilers could have adverse health effects on small, localized areas. **In addition, any fuels blended with organics and illegally burned, in apartment houses or institutional boilers, for example, should be expected to reduce the lives of these boilers through corrosion.**

To assess the role that boilers currently play in hazardous waste management nationwide, it is necessary to know what compounds are being burned, in which facilities, and with what DREs. **Without reporting requirements for coincineration, information is seriously lacking.** Currently, boilers may be burning twice the volume of ignitable hazardous waste that is being incinerated. Except for those from petroleum refining, all were discharged to the environment until environmental, handling, or increasing primary fuel costs encouraged their use as a fuel.[38] Of the entire spectrum of burnable waste, those having the highest Btu content are attracted to boilers. This may have economic effects on regulated incineration, because some hazardous waste incinerators could also benefit from the fuel value of the same waste used as auxiliary fuel in boilers.

5. **Multiple hearth incinerators.**—These use a vertical incinerator cylinder with multiple horizontal cross-sectional floors or levels where waste cascades from the top floor to the next and so on, steadily moving downward as the wastes are burned. These units are used **primarily** for incineration of sludges, particularly those from municipal sewage sludge treatment and, to a much lesser extent, certain specialized industrial sludges of generally a low-hazard nature. They are used almost exclusively at industrial plants incinerating their sludges on their own plant site for the latter cases.[39] Such incinerators are not well suited for most hazardous waste for two reasons: they exhibit relatively cold spots, and the waste is introduced relatively close to the top of the unit. Because hot exhaust gases also exit from the top, there is the potential for certain volatile waste components to short-circuit or "U-turn" near the top of the incinerator and exit to the atmosphere without spending an adequate time in the hot zone to be destroyed. This may be improved by having a separate afterburner chamber, but this option does not appear to have become accepted in the hazardous waste field.[40]

At least one brief test of a typical multiple hearth furnace was conducted in the early 1970's, in which the sewage was "seeded" with a small quantity of pesticide material. Although the pesticide was not detected in the exhaust, the researchers became aware of the short-circulating and residence-time problems and did not pursue the application of multiple hearths to hazardous wastes any.

6. **Fluidized bed combusters.**—This is a relatively new and advanced combuster design being applied in many areas. It achieves rapid and thorough heat transfer to the injected fuel and waste, and combustion occurs rapidly. Air forced up through a perforated plate, maintains

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[35] M. Turgeon, Office of Solid Waste, Industrial and Hazardous Waste Division, EPA, personal communication, January 1983.

[36] Olexsey, op. cit.

[37] C. C. Shih and A. M. Takata, TRW, Inc., "Emissions Assessment of Conventional Stational Combustion Systems: Summary Report" prepared for the Office of Research and Development, EPA, September 1981.

[38] EPA "Technical Overview of the Concept of Disposing of Hazardous Wastes in Industrial Boilers," op. cit.

[39] *Alternatives to the Land Disposal of Hazardous Wastes*, op. cit.

[40] Oppelt, op. cit.

a turbulent motion in a bed of very hot inert granules. The granules provide for direct conduction-type heat transfer to the injected waste. These units are compact in design and simple to operate relative to incinerators. Another advantage is that the bed itself acts as a scrubber for certain gases and particulates. Its role in hazardous waste may be limited to small and specialized cases due to difficulties in handling of ash and residuals, low throughput capacity and limited range of applicable waste feeds.[41]

There are presently only about 200 such combusters in the United States, used chiefly for municipal and similar sludges. About nine are used for hazardous waste.[42] Existing fluidized bed combusters are sparsely distributed and relatively small. Future applications of fluidized bed technology to hazardous waste is likely to occur at new facilities built specifically for this purpose rather than at existing municipal facilities.

Recent EPA testing at the Union Chemical Co., Union, Me., is still being evaluated. Early test results are mixed with regard to 99.99 percent destruction.[43] The simplicity of this technology and its ease of operation seem to indicate high reliability for achieving those levels of destruction and wastes for which it will prove to be applicable. A catalytic, lower temperature fluidized bed technology is being developed which may have lower energy costs, and may be more applicable to hazardous waste destruction.[44] However, incompatibilities between catalysts proposed on various hazardous waste may present problems to overcome.

7. **Incineration at sea.**—This is simply incinerator technology used at sea, but without stack gas scrubbers. (The buffering capacity of the sea and sea air is the reason for the lack of a scrubber requirement.) Free from the need to attach scrubbers, marine incinerator designers can maximize combustion efficiency in ways that land-based incinerators cannot.[45] Incinerators based on oil drilling platforms would further be freed from accommodating rolling ship motion.

Various EPA monitoring of test commercial burns of PCBs and government burns of herbicide Agent Orange and mixed organochlorines in the mid and late 1970's confirmed the 99.99+ percent destruction capability for liquid injection incineration used at sea.[46] Current technology exists only for liquids. Rotary kilns could be adapted to ships and more readily to oil drilling platforms.

There exists considerable controversy about the test burns recently conducted for PCBs destruction onboard the M.T. Volcanus. Data results are not yet available. Major concerns are whether the land and marine alternatives represent the same environmental risk and if the performance standards are evenly applied. EPA's view is that they represent roughly the same risk.[47] Regarding the performance standards, it should be recognized that the scrubbing the exhaust gas of land-based incinerators may be providing the fourth nine in their DRE performance. Thus, an at-sea DRE of 99.9 percent may be more similar to the land-based DRE of 99.99 percent than it may appear. The contribution of scrubbers to DRE values are not well known.

Additional concerns about incineration at sea include: stack gas monitoring, which is difficult enough on land and perhaps more so on a ship at sea, and the risk of accidents near shore or at sea. The ecological effects of a spill of Agent Orange on phytoplankton productivity could be substantial.[48] Storage facilities necessary for drilling platform-based incineration may involve still higher spill risks. Public opposition to hazardous waste sites applies also to storage of waste at ports.

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[41] *Alternatives to the Land Disposal of Hazardous Wastes*, op. cit.

[42] Proctor and Redfern, Ltd., and Weston Designers Consultants, "Generic Process Technologies Studies" (Ontario, Canada: Ontario Waste Management Corp., System Development Project, August 1982).

[43] J. Miliken, Environmental Protection Agency, personal communication, November 1982.

[44] R. Kuhl, Energy Inc., Idaho Falls, Idaho, personal communication, January 1983.

[45] K. Kamlet, National Wildlife Federation, *Ocean Dumping of Industrial Wastes*, B. H. Ketchum, et al. (ed.) (New York: Plenum Publishing Corp., 1981).

[46] D. Oberacker, Office of Research and Development, IERL, Environmental Protection Agency, Cincinnati, Ohio, personal communication, December 1982.

[47] Ibid.

[48] Kamlet, op. cit.

Other High Temperature Industrial Processes

Other types of applicable combustion processes including metallurgical furnaces, brick and lime kilns, and glass furnaces, are examples of existing industrial technologies which might be investigated as potential hazardous waste destruction alternatives.[49] There is no reporting of such uses that may be occurring, and no DRE data have been collected. The beneficial use exclusion may apply to many of such practices.[50] However, objectives of such processes are not necessarily complementary or supportive of high DRE. The technical potential for hazardous waste destruction and need for regulation of such practice needs investigation.

Emerging Thermal Destruction Technologies

Undue importance should not be placed on the distinction between current and emerging technologies. The intent is merely to distinguish between technologies currently "on the shelf" and those less commercially developed for hazardous waste applications.

Pyrolysis.—This occurs in an oxygen deficit atmosphere, generally at temperatures from 1,000° to 1,700° F. Pyrolysis facilities consist of two stages: a pyrolyzing chamber, and a fume incinerator. The latter is needed to combust the volatilized organics and carbon monoxide produced from the preceding air-starved combustion. The fume incinerator operates at 1,800° to 3,000° F. The pyrolytic air-starved combustion avoids volatilization of any inorganic components and provides that inorganics, including any heavy metals, are formed into an insoluble easily handled solid char residue. Thus, air pollution control needs are minimized.[51]

Pyrolysis has been used by the Federal Government to destroy chemical warfare agents and kepone-laden sludge and by the private sector to dispose of rubber scrap, pharmaceutical bio-sludge, and organic chlorine sludges. Most recently, pilot plant test burns on chlorinated solvents from a metal-cleaning plant have been destroyed with 99.99 percent destruction.[52]

Broader application would await much more equipment development and testing. Among the potential problems with pyrolysis are:

- Greater potential for toxic and refractory PICs formation than with combustion in air. The reducing atmosphere produces larger amounts of these compounds, and they may pass through the off-gas afterburner.
- Production of an aqueous tar that may be difficult to dispose in either a landfill or an incinerator.
- Substantial quantities of auxiliary fuel may be required to sustain temperature in the afterburner.[53]

Commercially, high throughput (up to 6,500 lb/hr) and required air pollution control requirements may be key future benefits. However, maintenance costs due to moving parts, and the need for well-trained operators may be relatively high.[54]

Molten Salt Reactors.—These achieve rapid heating and thorough mixing of the waste in a fluid heat-conducting medium. Liquid, solid, or gaseous wastes are fed into a molten bath of salts (sodium carbonate or calcium carbonate). Solids must be sized to 1/4- or 1/8-inch pieces in order to be fed into the bed. The bed must be initially preheated to 1,500° to 1,800° F. Provided that the waste feed has a heating value of at least 4,000 Btu/lb, the heat from combustion maintains the bed temperature, and the combustion reactions occur with near completion in the bed instead of beyond it. The sodium carbonate in the bed affects neutralization of hydrogen chloride and scrubbing of the product gases. Thus, the bed is responsible for decomposition of the waste, removal of the waste residual, and some off-gas scrubbing. A bag house for particulates completes air pollution control and the removal system.[55] (See fig. 9.)

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[49] PEDCO Environmental Services, Inc., "Feasibility of Destroying Hazardous Wastes in High Temperature Industrial Processes," for the Office of Research and Development, IERL, EPA, Cincinnati, Ohio, May 1982.

[50] 40 CFR, sec. 261 (c)(2).

[51] *Alternatives to the Land Disposal of Hazardous Wastes*, op. cit.

[52] Oppelt, op. cit.

[53] Ibid.

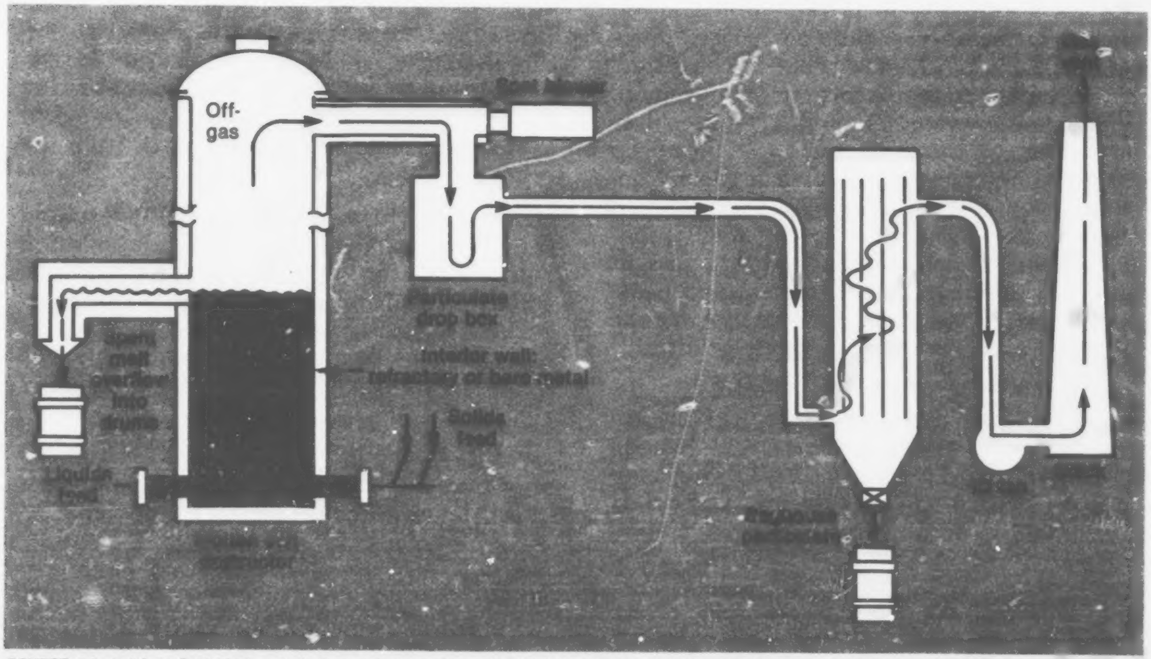
[54] *Technologies of the Treatment and Destruction of Organic Wastes as Alternatives to Land Disposal*, op. cit.

In EPA tests, a pilot scale unit (200 lb/hr) destroyed hexachlorobenzene with DRE's exceeding 6 to 8-9's (99.9999-percent to 99.999999-percent destruction and removal) and chlordane with DREs exceeding 6 to 7-9's.[56] Rockwell International also claims 99.999-percent destruction efficiencies* from private tests on malathion and trichloroethane.

Reactor vessel corrosion has impeded development of molten salt destruction (MSD). Vessel corrosion is accelerated by temperature, reducing conditions (less than sufficient oxygen), and the presence of sulfur. Traditionally, MSD reaction vessels have been refractory lined, presenting operational and maintenance costs similar to those of conventional incinerators. Rockwell International offers an MSD system with a proprietary steel alloy reactor vessel. This vessel is warranted for 1 year if the system is operated within specified ranges of temperature, excess air, and melt sulfur content.[57]

Ash as well as metal, phosphorous, halogen, and arsenic salts build up in the bed and must be removed. In the case of highly chlorinated waste (50 percent or more) the rate at which salt must be removed approaches the rate of waste feed. Both the salt replacement (or regeneration) and residual disposal determine economic viability for a given application. In pro-

Figure 9.—Molten Salt Destruction: Process Diagram



SOURCE: Adapted from S. Y. Yosim, et al., Energy Systems Group, Rockwell International, "Molten Salt Destruction of HCB and Chlordane," EPA contract No. 68-03-3014, Task 21, final draft, January 1983.

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[55] Ibid.

[56] S. Y. Yosim, et al., Energy Systems Group, Rockwell International, "Molten Salt Destruction of PCB and Chlordane," EPA contract No. 68-03-3014, Task 21, final draft, January 1983.

*Not DRE; small amounts removed in bed salts and baghouse treatment were not measured.

[57] J. Johanson, Rockwell International, Inc., personal communication, January 1983.

posed commercial ventures, sodium chloride residue would be landfilled and calcium chloride would be sold as road salt or injected deep well.[58]

The process is intended to compete with rotary kilns and may find application for a broad market of wastes that are too dilute to incinerate economically. However, water in the waste feed, as with any incineration technology, uses up energy in evaporation. Due to the extremely high DREs demonstrated in pilot scale tests, the process is expected to be very attractive for destroying the highly toxic organic mixtures and chemical warfare agents, which currently present serious disposal problems. Rockwell International is in final negotiations with two commercial ventures in California and Canada. Commercial-scale units offered are 225 and 2,000 lb/hour.[59]

High Temperature Fluid-Wall Reactors.—In these reactors, energy is transferred to the waste by radiation (rather than by conduction and convection as in the above processes). A porous central cylinder is protected from thermal or chemical destruction by a layer of inert gas. The gas is transparent to radiation, and the cylinder is heated by radiation from surrounding electrodes to 3,000° to 4,000° F. The refractory cylinder reradiates this energy internally to the passing waste.[60] The important result is very rapid and thorough heating of the waste stream for complete combustion or generation. The speed of the heating presents little opportunity for the formation of intermediate products for incomplete combustion that present concerns in conventional incineration processes. Also, process control is good since the radiation is directly driven by electricity.

A bench-scale reactor (¼ lb/min) has destroyed PCBs in contaminated soil (1 percent by weight) with 99.9999 percent DRE.[61] In addition, the Thagard Research Corp., which conducted the tests, claims that it has privately burned hexachlorobenzene with 99.9999 percent DRE in a 10 ton per day unit.[62] A commercial-scale unit (20 to 50 tons per day) is operated as a production unit by a licensee in Texas, which has agreed to allow Thagard to continue hazardous waste destruction demonstration burns there.[63] In December 1982, California and EPA conducted demonstration burns of some gases that are difficult to destroy thermally—1,1,1-trichloroethane, carbon tetrachloride, dimethyl chloride, Freon 12®, and hexachlorobenzene. Results are currently being assessed.

Further scaleup may be needed to provide commercial throughput, and this will involve larger ceramic cores. The effects of thermal stresses on the life of the cores present the major untested concern for scale up.

Near-term commercialization of the Thagard reactor is planned. During 1983, a Miami investment firm is expected to underwrite the development of a mobile reactor, reducing breakdown and setup time from several weeks to only a few days. This will facilitate the collection of test burn performance at potential applications sites.[64] Also, Southern California Edison Inc. is considering the process for future destruction of PCB-laden soil and for stabilization of a variety of its heavy metal-bearing liquid waste. The utility is also interested in selling byproducts of carbon black from the process.[65]

In addition to its potential mobility resulting from its compact design the only air pollution control need for the fluid wall reactor may be a bag house to control particulates. The process is not expected to be economically competitive with conventional incineration, but will be applicable especially to contaminated soils and silts.

Plasma-Arc Reactors.—These use very high energy free electrons to break bonds between molecules. A plasma is an ionized gas (an electrically conductive gas consisting of charged and neutral particles). Temperatures in the plasma are in excess of 50,000° F—any gaseous organic compounds exposed to plasma are almost instantly destroyed. Plasma arc, when applied to waste disposal, can be considered to be an energy conversion and transfer device. The electrical energy input is transformed into a plasma. As the activated components of the plasma decay, their energy is transferred to waste materials exposed to the plasma. The wastes are then atomized, ionized, and finally destroyed as they interact with the decaying plasma species. There is less opportunity for the formation of toxic PICs. Most of the destruction occurs without progression of reactions which could form them.[66]

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[58] Ibid.

[59] Ibid.

[60] *Technologies for the Treatment and Destruction of Organic Wastes as Alternatives to Land Disposal,* op. cit.

[61] E. Matovitch, Thagard Research Corp., personal communication, January 1983.

[62] Ibid.

[63] Ibid.

[64] Ibid.

[65] E. Faeder, Southern California Edison Power Co., personal communication, January 1983.

Private tests conducted for the Canadian Government have demonstrated 99.9999999 percent (i.e., 9-9's) destruction on pure transformer fluid (58 percent chlorine by weight).[67] Depending on the waste, the gas produced has a significant fuel value.[68] A high degree of process control and operational simplicity are additional advantages. For halogenated waste (a major market target), the gases would have to be scrubbed but the scrubbers needed are very small.

The process is in the public domain and nearing commercialization. The developer plans to market mostly small, self-contained, mobile units. Costs are intended to be competitive with incineration.[69] The first commercial application is planned to be in operation in July 1983.

Wet Oxidation.—Proven in commercial application, wet oxidation processes can destroy reliably nonhalogenated organic waste (e.g., cyanides, phenols, mercaptans, and nonhalogenated pesticides). The oxidation reactions are fundamentally the same as in combustion but occur in liquid state. Since it is not necessary to add large quantities of air as in incineration, potentially contaminated gas emissions are avoided. The reactions take place at temperatures of 430° to 660° F (and pressures of 1,000 to 2,000 psi). For many applicable waste feeds, the oxidation reaction resulting produces enough heat to sustain the process, or even to produce low pressure steam as an energy byproduct. The oxidation reactions typically achieve 80 percent complete decomposition to carbon dioxide and water, and partial decomposition to low molecular weight organic acids of the remaining waste feed.[70] Currently, the process remains commercially applicable to aqueous organic waste streams which are too dilute for incineration, yet too toxic for biological treatment.

Still in development are catalytic modifications to the wet oxidation process, aimed at the more stable highly chlorinated organics. Bench-scale tests conducted by I. T. Enviroscience have demonstrated that a bromide-nitrate catalyst promotes completeness of oxidation. Should this process achieve destructions similar to those of incineration, its lack of air emissions, and the ease of using performance monitoring would be advantageous.[71]

Super Critical Water.—At temperatures and pressures greater than 374° C and 218 atm, water becomes an excellent solvent for organic compounds and can break large organic molecules down into molecules of low molecular weight.[72] In a system patented by Modar, Inc., injected oxygen completely oxidizes the lower molecular weight molecules to carbon dioxide and water. DDT, PCBs and hexachlorbenzene have been destroyed with efficiencies exceeding 99.99 percent in bench-scale testing.[73] Costs are expected to be highly dependent on scale.[74] If high-destruction efficiency is maintained through scaleup, this could be an attractive alternative to incineration.

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[66] C. C. Lee, Office of Research and Development, IERL, Environmental Protection Agency, personal communication, January 1983.

[67] Plasma Research Inc., unpublished test results, January 1983.

[68] *Alternatives to the Land Disposal of Hazardous Wastes*, op. cit.

[69] T. Barton, Plasma Research Inc., personal communication, January 1983.

[70] P. Shaefer, Zimpro, Inc., personal communication, November 1982.

[71] Oppelt, op. cit.

[72] M. Modell, "Destruction of Hazardous Waste Using Supercritical Water," paper delivered at the 8th Annual Research Symposium on Land Disposal, Incineration, and Treatment of Hazardous Wastes (Fort Mitchell, Ky.: Environmental Protection Agency, Mar. 8, 1982).

[73] Ibid.

[74] *Alternatives to the Land Disposal of Hazardous Wastes*, op. cit.

Biological Treatment

Conventional biological treatments use naturally occurring organisms to degrade or remove hazardous constituents. In contrast, biotechnology uses bacteria which have been selected from nature, acclimated to particular substrates, and mutated through methods such as exposure to ultraviolet light for fixation of the adapted characteristics. Many toxic substances cannot be degraded biologically, although they may be effectively removed from a waste stream this way. Types of conventional biological techniques, waste stream applications, and their limitations are listed in table 29. These techniques have found widespread use for treatment of municipal and industrial wastes to prevent the formation of odorous gases, to destroy infectious micro-organisms, to remove nutrients for aquatic flora, and to remove or destroy some toxic compounds. Several biological techniques may be used as a series of steps to treat a waste, including ending with landfarming (also called land spreading or land treatment). The latter refers to the deposit of a waste, or some sludge or residue from a treatment, onto land or injected some small distance beneath the surface. Naturally occurring organisms in the soil degrade the waste, usually organic, and periodic plowing may be necessary to ensure adequate oxygen levels for degradation.

The physical, chemical, or biological processes that can be used to eliminate or reduce the hazardous attributes of wastes exist in as many forms as those processes used to manufacture the original material. All of these treatments produce waste residuals; usually a liquid and a solid waste. The hazardous characteristics of these waste residuals must be evaluated in terms of the objective desired for their final disposition or recovery. Without such an objective it is difficult to evaluate the benefit, either economic or environmental, of applying the treatment process. These treatments *can* result in merely changing the form or location of the waste. For example, concentrating organics from a dilute waste stream does not necessarily provide any benefit in terms of increased protection of health. If this separation and concentration treatment allows the waste constituent to be recovered or, alternatively, makes a destruction technology viable, the treatment has been beneficial.

Residuals from hazardous waste treatments are discharged to surface waters, to publicly owned wastewater treatment works (POTWs) or are sent to landfills or land treatment disposal. To the extent that the treatments considered below can reduce the toxic characteristics of wastes through destructive or degradative reactions, they are similar in their effect to thermal destruction technologies. To the extent that they are able to mitigate specific hazard characteristics, they render the wastes nonhazardous. And, to the extent that they reduce the mobility of the waste, they reduce the interaction of land-disposed wastes with the environment.

Many references exist describing unit physical, chemical, and biological processes and how they may be combined. This discussion will not attempt to duplicate any such descriptive listings. Table 30 lists the established applications. Selection of one or several processes depends on such factors as waste feed concentration, desired output concentration, the effects of other components in the feed, throughput capacity, costs, and specific treatment objectives.

Landfills

Landfilling is the burial of waste in excavated trenches or cells. The waste may be in bulk form or containerized. In the early 1970's, landfills specifically designed to contain industrial waste were constructed.* Experience with the operation and construction of these more advanced landfills has been an evolutionary process, and is ongoing.

Over time, fractions of the waste can be released from the landfill, either as leachate or as volatilized gases. The objective of landfilling design is to reduce the frequency of occurrence of releases so that the rate of release does not impair water or air resources.* Liquids are able to leak through compacted clays or synthetic lining materials. Reducing the potential for migration of toxic constituents from a landfill requires minimizing the production of liquids and controlling the movement of those that inevitably form.

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*In 1972, Chemtrol announced the opening of the reportedly first landfill designed to securely contain hazardous industrial waste.

Liquids can enter a landfill in several ways:

- by disposal of free liquid waste,
- by evolution from sludges and semisolids,
- from precipitation infiltrating through the cover into the landfill cell, and
- from lateral movement of ground water infiltrating through the sides or the bottom of the cell.

No one disputes the presence of liquids in a landfill; the objective of good landfill design is to control their movement. Flow of liquids through soil and solid waste occurs in response to gravity and soil moisture conditions. When the moisture content within a landfill exceeds field capacity, liquids move under saturated flow, and percolate to the bottom. Liquid movement under saturated conditions is determined by the hydraulic force driving the liquid, and the hydraulic conductivity of the liner material. Hydraulic force can result in discharge through a liner.

Landfills can be designed to reduce migration, but there is no standard design. Advanced designs would have at least the following features: a bottom liner, a leachate collection and recovery system, and a final top cover.

Figure 10 depicts a landfill with these engineered features. Taken together, these features are intended to make it physically easier for water to run off the surface cover instead of infiltrating it and to collect leachate through the drainage layer instead of permeating the liner. Beds constructed of graded sizes of gravel and sand are sometimes used as intermediate drainage layers to speed internal dewatering.

Applicable Wastes

Virtually any waste can be physically buried in a landfill; however, landfills are least effective at controlling the migration of waste constituents which are volatile and soluble. **Landfilled wastes that are toxic, persistent, soluble, and volatile are most likely to present a risk of human exposure.** Federal regulations outline pretreatment requirements for wastes which are ignitable, reactive, and/or corrosive* but do not address characteristics of persistence, toxicity, volatility, or solubility.

Current Use and Evaluation.—It is estimated that 270 landfills are currently in use for hazardous waste disposal. (See ch. 4 for discussion of facility data.) These facilities are among those which may apply for RCRA authorization as hazardous waste disposal facilities.

Existing landfills are constructed and operated with varying degrees of sophistication. Numerical information on the distribution of landfills that incorporate particular control features is not available. It is likely, however, that many existing facilities do not have any sort of constructed bottom liner nor any leachate or gas collection systems.[75] Often, existing facilities were sited with little regard to local hydrogeology. The degree of sophistication of existing landfill facilities ranges from those that have minimal control features and accept virtually any waste, to those which combine a favorable site location with waste pretreatment or a restrictive waste policy, engineered control features, leak detection, and ground water monitoring programs. Landfills also vary in capacity. Most are small (burying less than

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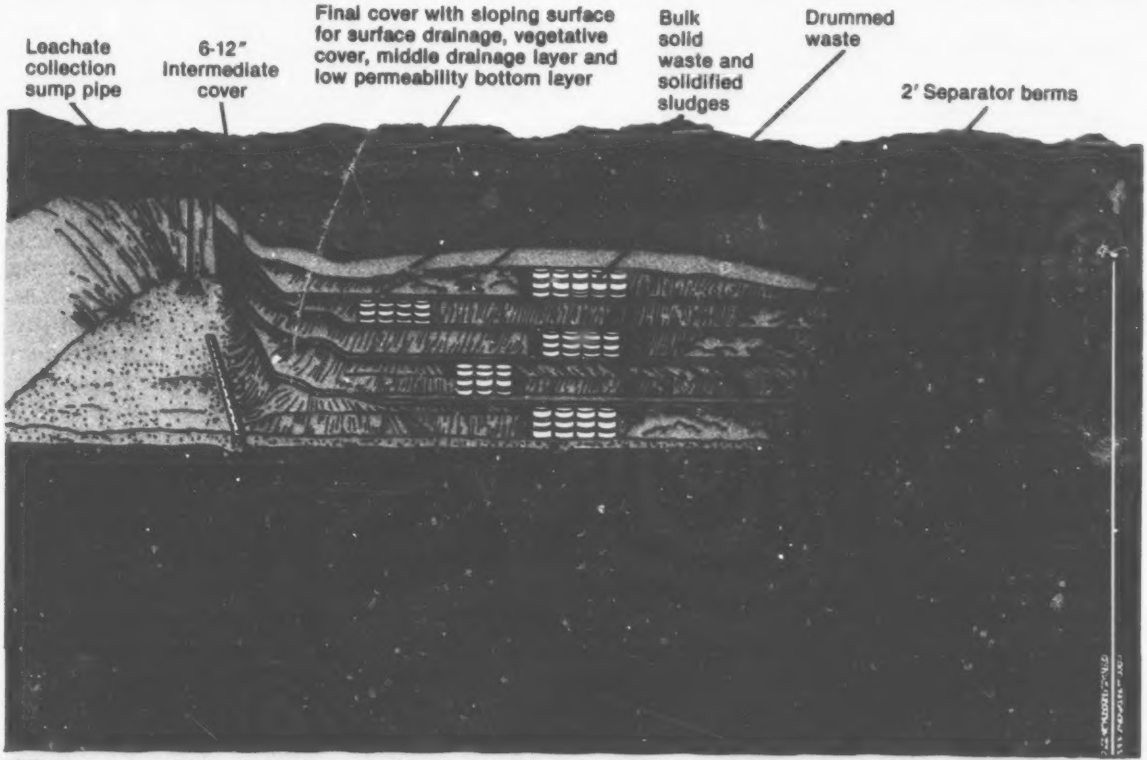
*Criteria for determining "impairment" of ground water are currently defined by a statistically significant increase over background levels, or exceeding established limits. See discussion on ground water monitoring requirements, ch. 7. No criteria currently exist for impairment of air resources; research is underway to determine the magnitude and potential severity of gaseous emissions.

*More detail on regulatory requirements are discussed in the subsequent section titled "Technical Regulatory Issues," see also ch. 7.

[75] Environmental Protection Agency, *Final EIS, Subtitle C, Resource Conservation and Recovery Act of 1976*, app. D, SW-189c, 1980.

Figure 10.—Generalized Depiction of a Hazardous Waste Landfill Meeting Minimum Federal Design Criteria


Leachate collection sump pipe
6-12" intermediate cover
Final cover with sloping surface for surface drainage, vegetative cover, middle drainage layer and low permeability bottom layer
Bulk solid waste and solidified sludges
Drummed waste
2' Separator berms

NOTE: This is not a prescriptive or exact depiction of a landfill design, or is it necessarily representative of all hazardous waste landfills. Alternative designs are allowed. See also figure 12 for detail on single and double liner design.

SOURCE: Office of Technology Assessment, adapted from Draft RCRA Guidance Document, Landfill Design, Liner Systems and Final Cover, July 1982, and USEPA Draft SW-867, SW-869, SW-870, Municipal Environmental Research Laboratory, Cincinnati, Ohio, September 1980.

16,500 tons per facility in 1981).[76] Smaller landfills may tend to use less sophisticated control measures.

Long-term landfill performance is determined by:

- the **reliability** of the leachate collection system and the **longevity** of liner(s), and top cover;
- the **hydrogeological** characteristics of the site;
- the characteristics of the **waste** prior to disposal; and
- daily **operations** at the site—e.g., the liquids management strategy at the site, the testing practiced by the operator, and the level of quality control over site operations.

Engineered Control Features

A landfill has three primary engineered control features: a bottom liner(s), a leachate collection system, and a cover. The bottom liner(s) retard the migration of liquids and leachate from the landfill cells. Bottom liners are constructed of compacted clay, a clay and soil mixture, or synthetic material—often synthetic membranes. Leachate is collected through a series of pipes buried in a drainage bed placed above the bottom liner. A mechanical pump raises the leachate through standpipes to the surface. The final cover reduces infiltration of precipitation into the closed landfill. Intermediate covers can be applied for the same purpose during operation of the landfill. Table 33 summarizes function and failure mechanisms for each of these components.

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[76] Westat, Part A Universe Telephone Verification Contract No. 68-01-6322, Nov. 11, 1982.

1. **Bottom liners.**—The function of a liner placed beneath a landfill is to **retard** the migration of leachate from the landfill so that it can be collected and removed. For synthetic liners, retarding migration is dependent on their characteristic low permeability and compatibility with a wide spectrum of wastes. For some compacted clay liners, migration of leachate is retarded both by their low permeability and by the capacity of clays to decrease the concentration of certain waste constituents in the leachate through a variety of chemical reactions—e.g., precipitation, filtration, adsorption, or exchange of charged chemical species with the clay particles.[77]

All liners exhibit some measure of hydraulic conductivity; that is, they allow passage of liquid under hydraulic pressure.[*] Based on laboratory and field testing, typical ranges of conductivity are approximately 10^{-11} to 10^{-14} m/sec for synthetic membranes, and 10^{-9} to

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[77] See for example, M. Lewis, "Attenuation of Polybrominated Biphenyls and Hexachlorobenzene by Earth Materials" (Washington, D.C.: Environmental Protection Agency, No. 600/S2-81-191, December 1981); and L. Page, A. A. Elseewi, and J. P. Martin, "Capacity of Soils for Hazardous Inorganic Substances" (Riverside, Calif.: University of California, August 1977).

[*] For low permeability synthetics, the rate of fluid passage is difficult to measure because it is so close to passage in the vapor phase. Synthetics are tested under pressure, and their permeability is back-calculated.

Table 33.—Engineered Components of Landfills: Their Function and Potential Causes of Failure

Function	Potential causes of failure
Cover:	
To prevent infiltration of precipitation into landfill cells. The cover is constructed with low permeability synthetic and/or clay material and with graded slopes to enhance the diversion of water.	• After maintenance ends, cap integrity can be threatened by desiccation, deep rooted vegetation, animals, and human activity. • Wet/dry and freeze/thaw cycles, causing cracking and increased infiltration. • Erosion; causing exposure of cover material to sunlight, which can cause polymeric liners to shrink, break, or become brittle. • Differential settling of the cover, caused by shifting, settling, or release of the landfill contents over time. Settling can cause cracking or localized depressions in the cover, allowing ponding and increased infiltration.
Leachate collection and recovery system:	
To reduce hydrostatic pressure on the bottom liner, and reduce the potential for flow of leachate through the liner. Leachate is collected from the bottom of the landfill cells or trenches through a series of connected drainage pipes buried within a permeable drainage layer. The collection leachate is raised to the surface by a mechanical pump.	• Clogging of drainage layers or collection pipes. • Crushing of collection pipes due to weight of overlying waste. • Pump failures.
Bottom liner:	
To reduce the rate of leachate migration to the subsoil.	• Faulty installation, damage during or after installation. • Deformation and creep of the liner on the sloping walls of the landfill. • Differential settling, most likely to where landfill is poorly sited or subgrade is faulty. • Structural failure of the liner in response to hydrostatic pressure. • Degradation of liner material resulting from high strength chemical leachate or microbial action. • Swelling of polymeric liners, resulting in loss of strength and puncture resistance. • Chemical extraction of plasticizers from polymer liners.

SOURCE: Office of Technology Assessment.

10^{-11} m/sec for clay liners.[78] The units of measure for hydraulic conductivity involve a thickness component. Thus, although an intact synthetic material has a very low conductivity, they are very thin.* In comparison, clay liners often range in thickness from several feet to several yards.

All liner materials are subject to breaches in their physical integrity. With the exception of obvious chemical incompatibilities that can rapidly deteriorate a liner, these failures can be a more important factor in increasing the rate at which liquids can migrate than the inherent conductivity of the liner. Two major sources of structural failure for all liners are incorrect installation and damage during or shortly after installation.

Proper installation of any liner requires considerable technical expertise. For clay liners, the moisture content of the clay prior to compaction and the method of compaction are critical factors. For example, varying the water content in a clay prior to compaction can result in differences of two orders of magnitude in the permeability of the clay.[79] For synthetic liners, proper welding of the seams joining the panels of the liner and avoiding damage to the dimensional stability of the membrane fabric are critical. Damage to liner fabric stability can occur while stretching synthetic liners over the large areas involved in landfills. For example, a single large panel of synthetic material may cover 20,000 ft² feet and weigh 10,000 lb.

Preparation of the soil under the liner is critical to the performance of all liners. Proper preparation is necessary to prevent local deformational stresses. Clay liners are likely to respond to deformational stress by shearing. Depending on the characteristics of the synthetic material used, they may respond by stretching or tearing. In the past, liners were often installed by contracting firms which had minimal technical expertise and little motivation to be assiduous in their installation practices. More recently, manufacturers of synthetic liners and designers of clay liners are combining the sale of their products with actual installation, in order to maximize performance of their product and protect business.[80] **Certification of proper liner installation is not currently required by EPA, but it is required by several states.**[81]

Liners are also subject to damage after installation. One source of damage is vehicular traffic at the site—e.g., the heavy equipment used to spread sand and gravel directly on top of the liner to place the drainage layer for collection of leachate. Synthetic liners are vulnerable to localized tears and punctures. Clay liners can also be damaged after installation—e.g., slumping of the clay can occur on side slopes.[82] Once a liner has been covered by the drainage layer, it is impossible to visually inspect it for damage.

Chemical reactions between liner and leachate can significantly increase liner permeability.[83] [84] [85] For example, organic or inorganic acids may solubilize certain minerals within clays and a variety of organic liquids dissolve the monomers within PVC lines.

Laboratory tests can identify obvious chemical incompatibilities between a liner material and an expected leachate, and can also project general wear characteristics. (Table 5A-1 in app. 5A summarizes the findings of such tests.)

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[78] D. J. Folkes, Fifth Canadian Geotechnical Colloquium, "Control of Contaminant Migration by the Use of Liners," National Research Council of Canada, April 1982.

*Synthetic membranes are produced in thicknesses ranging from 0.5 millimeters (20 mils) to 2.5 milimeter (100 mils). J. P. Giroud and J. S. Goldstein, "Geomembrane Liner Design," *Waste Age*, September 1982.

[79] David E. Daniel, "Problems in Predicting the Permeability of Compacted Clay Liners," Symposium on Uranium Mill Tailings Management, Colorado State University, Geothermal Engineering Program, Ft. Collins, Colo., October 1981.

[80] R. Kresic, Midwest Accounts Manager for Schlegel Lining Technology, Inc., Ohio, personal communication, November 1982.

[81] D. Lennett, Environmental Defense Fund, personal communication, December 1982.

[82] Environmental Protection Agency, *Lining of Waste Impoundment and Disposal Facilities*, SW-870, ch. 4 "Failure Mechanisms," September 1980.

[83] Ibid.

[84] H. E. Haxo, "Interaction of Selected Liner Materials With Various Hazardous Wastes" (Cincinnati, Ohio: Environmental Protection Agency (NTIS No. 600/9-80-010)).

[85] D. Anderson, "Does Landfill Leachate Make Clay Liners More Permeable?" *Civil Engineering—ASCE*, September 1982, pp. 66-69.

However, laboratory data cannot directly predict performance under actual field conditions. Laboratory tests are conducted on only a small sample of the liner material; this presents problems for estimating field permeability of clays. Calculations of liner permeability based on field measurements demonstrate that laboratory estimates are frequently too low. Development of improved field techniques are underway.[86] [87] Also, laboratory tests cannot account for possible damage in the physical integrity of the liner material resulting from installation, operation, and long-term wear in the potentially harsh service environment of a landfill. This may compound problems in projecting the service life of synthetic liners.*

Further, testing for chemical compatibility requires prediction of expected leachate characteristics over time. This is difficult for landfills accepting a variety of waste types. Some landfill facilities segregate waste into cells to make leachate prediction simpler and more reliable.

2. **Leachate collection system.**—Leachate collection systems are a series of perforated drainage pipes buried at the lowest points within a landfill. These pipes are designed to collect liquids which flow under the influence of gravity to the low points. Once the collected liquids reach a predetermined level, they are pumped to the surface.[88] Overall, the system operates much like a sump pump in a household. Liquids that are recovered are tested for their hazardous characteristics. If the liquids are determined to be hazardous (under the RCRA criteria for hazardous waste), they are treated and discharged or redisposed in the landfill.[89]

The levels of leachate within a landfill will change with time in response to infiltration, pumping, and recharge rates. High leachate levels must be reduced by pumping in order to reduce hydraulic pressure on the bottom liner.[90] In general, doubling the height of the ponded liquid doubles the force driving the leachate through the liner.[91] Information from commercial landfill facilities show that liquids levels can reach over 10 ft. If the system is working properly, the leachate can easily be pumped out.[92] Conversely, pumping can be hampered by technical difficulties such as the inability of the cover to prevent further infiltration. In such cases, reducing leachate levels can take months to years.[93]

After landfilling operations end, leachate is required to be pumped out during the post-closure period "until leachate is no longer detected."[94] Failures in the collection system which impede leachate flow to the pump might be misinterpreted as the end of leachate generation. Some failures, such as poor leachate transmission through the filter beds or collapse of the drainage pipes, are both difficult to detect and to repair.

3. **Cover.**—After operations at the landfill have ceased, the final cover is installed. The function of the final cover is to reduce the infiltration of water and to provide a physical barrier over the waste. To do this, it must remain structurally sound over time. Covers can be constructed of layers of synthetic membranes, clays, and soil. Leachate standpipes pierce the cover in order to project into the landfill cells. Soil is placed over the cover, and vegetation is established to stabilize the soil.

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[86] D. E. Daniel, "Predicting Hydraulic Conductivity of Clay Liners" (Austin, Tex.: University of Texas, Department of Civil Engineering, 1982).

[87] R. E. Olson and D. E. Daniel, "Field and Laboratory Measurement of the Permeability of Saturated and Partially Saturated Fine Grained Soils" (Austin, Tex.: University of Texas, Department of Civil Engineering, June 1979).

*For example, manufacturers of synthetic lining material warranty their product for a specified time period (e.g., 10 to 30 years) against material defects in compounds and workmanship which would affect performance. However, the warranty can be voided if the liner material shall have been exposed to harmful chemicals, abused by machinery, equipment or persons, or if installation is inadequate.

[88] K. Malinowski, CECOS International, New York, personal communication, August 1982.

[89] Environmental Protection Agency, *Management of Hazardous Leachate*, SW-871, September 1980.

[90] EPA, op. cit., SW-870, 1980, sec. 5.6.

[91] D. Daniel, personal communication, October 1982.

[92] B. Simonsen, Vice President, IT Corp., and P. Vardy, Vice President of Waste Management, Inc., personal communication, December 1982.

[93] P. N. Skinner, "Performance Difficulties of 'Secure' Landfills in Chemical Waste and Available Mitigation Measures," American Society of Chemical Engineers, October 1980.

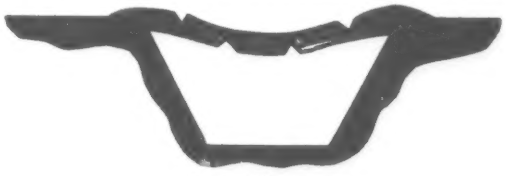
[94] 47 FR 32,366, July 26, 1982.

Covers are subject to a number of failure mechanisms (see table 33). Some of these, such as erosion or piercing of the cover by plant roots, can be reduced through proper and continued maintenance and repair of the site.* However, if maintenance ends, the integrity of the cover will be threatened by ubiquitous weathering processes, such as desiccation, erosion, and freeze/thaw cycles. Deep-rooted vegetation, burrowing animals, and human activity can also cause damage. Depending on the **site location** and **pretreatment** of the waste, the risk of leachate migration caused by infiltration through the cover may be reduced before the facility operator's maintenance responsibility ends. These factors are critical, since the cover is the primary line of defense against waste migration after the post-closure period.

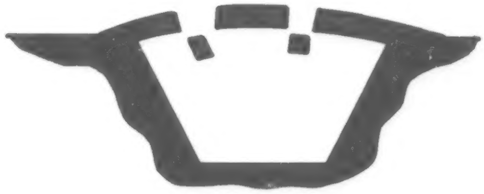
Other potential sources of cover damage cannot be prevented by simple maintenance. Foremost among these are subsidence damage and deterioration of synthetic membranes over time. Subsidence refers to the settling of the waste and the cover; subsidence damage has been identified by EPA as one of the most critical factors resulting in poor landfill performance.[88] Figure 11 depicts a cover designed with a gently sloping crown to facilitate runoff, and examples of cover failure. Ideally, the crown should be designed and constructed to compensate for estimated long-term subsidence. However, there are several factors which make this difficult.[89]

Comparatively uniform subsidence might be expected to occur for landfills containing one form of waste (i.e., a monofill). Many landfills, however, contain a variety of wastes, both containerized and in bulk. Bulk liquids and sludges

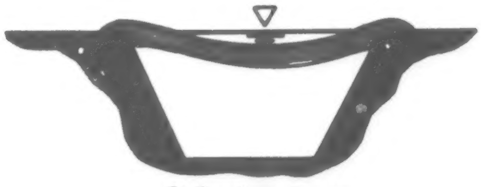
Figure 11.—Potential Failure Mechanisms for Covers



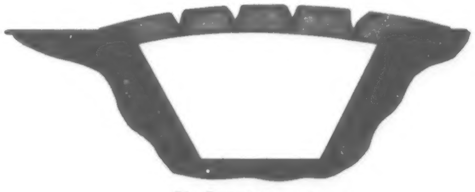
A) Cracking of cap due to settlement



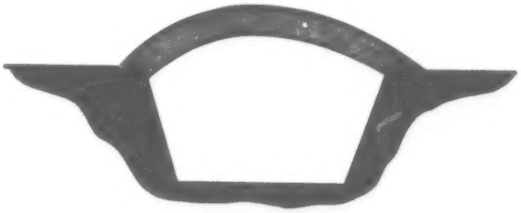
B) Collapse of cap into open voids



C) Ponding of water in depressions



D) Cracking of cap due to desiccation



E) Proper design

SOURCE: "Shallow Land Burial of Low-Level Radioactive Waste, David Daniel, AM, ASCE. Journal of Geotechnical Engineering Division, January 1983.

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*Under current regulations, the landfill operator is required to maintain the site for 30 years after closure. If the facility operator has met the requirements for monitoring and closure, the Post-Closure Liability Fund established under CERCLA can be used to pay the costs of monitoring, care, and maintenance of the site thereafter, and if funds are available. See ch. 7; also Public Law 96-510, sec. 107(k)(1).

[88] G. Dietrich, former Director of EPA's Office of Solid Waste, in testimony at the Mar. 11, 1982 public hearing on containerized liquids in landfills.

[89] Skinner, op. cit., pp. 17, 20-23.

provide little internal structural support. Vaporization may also be a problem. Containers do provide short-term support, but they deteriorate, often within a few years. The rate of container deterioration is difficult to predict; it depends on site- and waste-specific factors. It may not be possible to compact a mixed waste landfill sufficiently, e.g., compaction comparable to preparation of a building foundation. Further, the internal structure of the landfill cells is constructed of compacted support walls, which retain their original height while the wastes within settle. Cracking around the perimeter of the cover has resulted.[97] Finally, the extraction of collected leachate produces void spaces and exacerbates settling.

Some of these subsidence concerns are being addressed by landfill operators. For example, some commercial facilities place drummed waste on its side, a position providing less structural support, in order to hasten the collapse and settling of the buried drums.[98] This reduces future subsidence by enhancing the structural stability of the landfill prior to installing the final cover. Other facilities prohibit burial of liquids and emphasize treatment to enhance structural stability.[99]

Correction of Failure Mechanisms.—The failure mechanisms described can enhance the migration of waste constituents. The ability to correct potential failures is critical to landfill performance.

Detection of excessive contamination from leachate migration, either through a leak-detection system or external ground water monitoring, requires corrective action. Repairing the source of the leak is generally not possible. Liner repair requires: 1) locating the source of the leak, and 2) exhuming the waste. The first is difficult, although remote sensing techniques to locate leak sources are being developed.[100] Exhuming the waste is costly and potentially dangerous. Alternatively, pumping leachate can reduce the volume of leachate available for migration. Generally, leachate is removed by pumping from the collection system above the liner. OTA found little information on leak detection systems designed as secondary leachate removal systems, although this seems a promising area for future engineering design.

If infiltration through the cover is determined to be the cause of migration, the cover can be repaired (subsequent repairs may be necessary). The more complex and sophisticated the design of the cover, the more difficult and costly it is to repair. Cover repair may require carefully peeling back each protective layer until each is found to be sound. Cover repair generally requires partial reconstruction of gas collection and cover drainage systems, recompaction of soil layers, and revegetation of the surface soil. These procedures generally require work done by hand. Depending on the geographic location of the landfill, repair operations can be precluded during wet weather; the same conditions that exacerbate further damage.[101] Ultimately corrective actions at landfills may rely primarily on mitigating the **effects** (e.g., cleansing ground water, diverting contaminated plumes) of the failure rather than correcting the **cause** of the failure.

Hydrological Characteristics of the Site

Site hydrology encompasses the properties, distribution, and circulation of water on the land surface, in the soil and underlying rocks, and in the atmosphere. Hydrological information includes data on the interrelated effects of geological and climatic characteristics on the properties and circulation of water. Over geologic time, these processes have shaped the environment within which the landfill must operate.

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[97] P. Varty, Vice President, Waste Management Inc., personal communication, January 1983.

[98] For example, Waste Management Inc. and SCA Chemical Waste Services, Inc.

[99] J. Greco, Divisional Vice President, Government and Industry Affairs, Browing-Ferris Industries, personal communication, June 1982.

[100] A comparison of these techniques has been prepared by Waller, Muriel Jennings, and J. L. Davis, "Assessment of Technologies To Detect Landfill Liner Failures," in proceedings of the Eighth Annual Research Symposium, EPA 600/9-82-002, March 1982.

[101] Skinner, op. cit.

There are two key site characteristics critical to the design and operation of landfills: general climatic characteristics that determine the **amount of leachate generated** and the characteristics of the underlying geology that determine the **potential for liquids to migrate** and the **consequent risk** of migration from the site. The potential for leachate generation and migration can vary markedly depending on the characteristics of the site. An engineered landfill sited over many feet of native low-permeability clays, resting on unfractured bedrock, and in an area where evaporation historically exceeds precipitation is less likely to impair ground water. In contrast, an engineered landfill relying solely on a synthetic liner, sited on unconsolidated dredged fill material, overlying fractured bedrock, and in an area where precipitation historically exceeds evaporation, is more likely to result in migration of excess leachate.

EPA has established criteria for siting low-level radioactive waste landfills, which state that "locations for radioactive waste disposal should be chosen so as to avoid adverse environmental and human health impacts and wherever practicable to **enhance isolation** over time."[102] Current interim final regulations for hazardous waste disposal have only incentives (in terms of reduced monitoring requirements) for landfills sited in areas with exceptionally protective natural hydrology. No outright restrictions exist for sites with poor hydrological features.[103]

Characteristics of the Waste Prior to Disposal

A wide variety of wastes are currently landfilled. Certain waste characteristics and disposal methods make waste containment difficult. For example, landfilling bulk liquid waste plays an important role in site destabilization. One researcher notes that disposal of waste liquid has "changed little in the last 30 years."[104]

A variety of treatments can be used to improve the structural stability and reduce the mobility of landfilled waste. These techniques convert waste into a solid with greater structural integrity. **Stabilized or solidified waste are less likely to leach from a land disposal site than are untreated waste—even though the physical and chemical characteristics of the constituents of the waste may not be changed by the process.** Stabilization/solidification usually involves the addition of materials that ensure that the hazardous constituents are maintained in their least soluble form.

Stabilization/solidification processes can be categorized as follows:[105] [106]

- **Cement-based process.**—The wastes are stirred in water and mixed directly with cement. The suspended particles are incorporated into the hardened concrete.
- **Pozzolanic process.**—The wastes are mixed with fine-grained silicicous (pozzolanic) material and water to produce a concrete-like solid. The most common materials used are fly ash, ground blast-furnace slag, and cement-kiln dust.
- **Thermoplastic techniques.**—The waste is dried, heated, and dispersed through a heated plastic structure. The mixture is then cooled to solidify the mass.
- **Organic polymer techniques.**—The wastes are mixed with a pre-polymer in a batch process with a catalyst. Mixing is terminated before a polymer is formed and the spongy resin-mixture is transferred to a waste receptacle. Solid particles are trapped in this spongy mass.
- **Surface encapsulation.**—The wastes are pressed or bonded together and enclosed in a coating or jacket of inert material.

The type of waste most amenable to stabilization, solidification, and encapsulation techniques are inorganic materials in aqueous solutions or suspensions that contain appreciable amounts of metals or inorganic salts (e.g., metal-finishing waste). Metal ions in these residues are held as relatively insoluble ions in a crystalline lattice.

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[102] R. Abrams, "Comments to U.S. Environmental Protection Agency Regarding Proposed Amendments to 40 CFR 265: Special Requirements for Liquid Waste," 1982.

[103] FR vol. 47, July 26, 1982.

[104] Anderson, op. cit.

[105] State of California, op. cit.

[106] Martin, Oppelt, and Smith, "Chemical, Physical, Biological Treatment of Hazardous Wastes," September 1982.

Waste containing more than 10 to 20 percent organic substances are generally not good candidates for this treatment method. Their diverse properties interfere with the physical and chemical processes that are important in binding the waste materials together. Some solidifying reagents may never harden if the waste contains inhibiting materials. Silicate and cement reactions can be slowed by organics or by certain metals. Organic polymers can be broken down by solvents, strong oxidizers, strong acids, or by exposure to sunlight.

Solidification pretreatment provides extra environmental protection in land disposal of treatable residues. For specific wastes, certain chemical stabilization treatments so thoroughly immobilize toxic constituents in EPA approved tests that they have been tentatively removed from hazardous waste regulation.[107] Usually, however, some metal cations remain somewhat mobile. In addition, there are considerable objections to EPA's leaching test as a stimulation of landfill conditions.

Some of the stabilization processes result in products that have compression strengths similar to cement or concrete. The durability of stabilized waste to wet/dry and freeze/thaw cycles, however, has generally not been good. Stabilization/solidification processes generally improve the physical handling characteristics of the waste, enhance structural integrity of the landfill, and eliminate the "free-liquid" status of the waste. Mixing waste with various absorbents can also remove the free-liquid status, but generally leaves the toxic constituents more soluble and mobile than the chemical stabilization methods.

Current Landfill Practice

Many improvements in landfill operation have occurred since passage of RCRA. Furthermore, waste handlers, landfill designers, and liner manufacturers are taking steps to ensure their specific facility, product, or service contribution is used to its best effect. Examples of such actions are:

1. some facilities emphasize land burial of waste treatment residuals which are generally less toxic and mobile, than untreated waste;
2. some facility owners and/or operators have sought out especially protective hydrological settings for construction of landfills;
3. some facilities segregate wastes with similar characteristics. This facilitates leachate prediction and testing for liner comparability;
4. several waste handlers have established a strict prohibition against burial of liquids, in bulk or in containers;
5. some manufacturers of synthetic lining materials provide compatibility testing and installation with the sale of their product sale;
6. some firms are researching methods to incorporate the natural attenuation capacity of clays in their liner designs. That is, they attempt to correlate expected leachate characteristics to the attenuative capacity of the clay so that the leachate that eventually passes through meets specific water quality criteria; and
7. some landfill design firms are prospectively designing landfills to make corrective actions easier—e.g., to facilitate installation of a grout curtain to reduce lateral migration of ground water of contaminated leachate plumes.

Evaluation of Current Landfill Performance

Releases should be minimized, but there are substantial differences in philosophy about what this "minimization goal" means. The EPA narrative performance standard for landfills, states that landfill liners should **prevent** migration of leachate for the operating life of the fill (i.e., the lendfill system should be 100 percent effective in its control of leachate) and that migration should be minimized thereafter.[108] This criteria fails to recognize that, because of the potential failures discussed, complete prevention of migration even during the operating life is probably unattainable. In fact, RCRA standards for ground water quality recognize that complete prevention may not be necessary. These standards for contaminant levels in ground water will be the criteria against which landfill performance will be judged. Critics argue that evidence of contamination is a poor criterion because it may not be detected, could be widespread before it is detected, and aquifer cleanup is expensive and may be unachievable (see also "Technical Regulatory Issues").

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[107] F. Kelley, Stablex Corp., and H. Busby, Chemfix Corp., personal communication, November 1982.

[108] FR vol. 47, July 26, 1982, p. 32314.

The first generation of landfills designed specifically for disposal of hazardous waste are now in the ground.[109] Quantitative data on their current effectiveness is limited. Data provided by a study of four landfills in New Jersey, which had leak-detection systems installed, showed they began collecting between 45 to 75 gal/day within months of their construction.[110] Although controversial, this study concluded that the collection of liquids was due to failure of the primary liners. No landfills have been closed long enough to test the effectiveness of long-term maintenance or corrective actions. There is little quantitative evidence on which to project landfill performance, especially over the long term.

Future evaluations of landfill performance will depend on monitoring. The external ground-water monitoring currently required may not be sufficient (see ch. 7). In comparison to external monitoring, however, leak-detection systems embedded within a double liner may provide more reliable information on potential resource degradation and human exposure.

By examining how landfills work, their failure mechanisms, and available corrective measures, OTA's review of landfill performance resulted in two principle findings: 1) uncertainty remains about the performance capabilities of each of the control features of a landfill, and 2) greater use should be made of waste treatments which increase waste stability as well as reduce long-term mobility of waste constituents.

EPA is conducting additional analyses of failures that have occurred at existing sites.[111] Such analyses invariably indicate that poor performance can be attributed to poor operating practice, design, or maintenance. Operation of any facility will always be subject to error or misjudgment; this underscores the importance of site and waste characteristics, the necessity of designing for both reliable indicators of potential failure, and corrective action capability. There is room to improve in both of these areas.

The performance standards and minimum design requirements for new landfills are based on the experience gained in recent years. However, as noted frequently in the preamble to EPA's land disposal regulations, there is limited experience and operating data for landfills (or closed surface impoundments). This lack of information hampers the development of performance design guidance.[112] Laboratory and field testing of liners and covers is underway. Little is being done to monitor actual facility performance; yet it is unlikely that our current experience is adequate to anticipate all future difficulties. Without better information on actual facility performance, it will be difficult to evaluate landfills constructed according to minimum design requirements, or to evaluate alternative landfill designs. There are technical methods available to improve our information base.

In-situ instrumentation for systematically gathering data on the following performance indices has been suggested:[113]

1. leachate accumulation at sites other than manholes;

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[109] A. L. Kruger, "Alternatives to Landfilling Wastes" (Princeton, N.J.: Princeton University, Department of Chemical Engineering, Ph.D. Thesis, February 1982).

[110] Peter Montague, "Hazardous Waste Landfills: Some Lessons From New Jersey, *Civil Engineering—ASCE*, Septemer 1982, pp. 53-56, and more detailed unpublished draft.

[111] William L. Murphy Rohrer, Senior Environmental Scientist, Pope-Reid Associates, Inc., personal communication, January 1983.

[112] Comments to EPA regarding proposed rules, "Docket 3004, Permitting Standards for Land Disposal Facilities," prepared by the New York State Attorney General, Robert Abrams, Nov. 9, 1982.

[113] Ibid., p. 4.

2. stress/strain characteristics of synthetic membranes;
3. settlement of individual lifts inside the cells;
4. leachate delivery to leachate collection system;
5. differential and areal settlement of the cap;
6. seasonal moisture contents of the cap;
7. erosion rates of cap soils;
8. actual cap infiltration rates;
9. three-dimensional chemical conditions inside the cells, especially in the vicinity of the liner face;
10. gas evolution rates in particular cells; and
11. contaminent transport phenomena in soil liner.

Technical Regulatory Issues

The current regulatory framework will affect the future use, operation, and design of landfills. Liability requirements may encourage certain industry sectors to employ alternative treatment technology or waste reduction activities. If implemented, requirements to demonstrate financial responsibility for future corrective action may be an even greater incentive (see also ch. 7).

Current regulations will require upgrading the design of new facilities to include the use of liners, guidelines for waste pretreatment, leachate collection systems, and covers. Existing portions of facilities are broadly exempted from retrofitting that do not have the minimal control features of a liner or collection system.

The current regulations will influence the construction and operation of landfills. Key regulatory points with likely impacts on future use of landfills are:

- a preference for the use of artificial liners;
- minimal restrictions on the waste allowed to be landfilled; and
- minimal restrictions on the siting of landfills.

Influence on Liner Selection.—The current regulations state that liner materials for new hazardous waste landfills should not allow migration of leachate into the liner during the operating life of the facility. This could favor the selection of synthetic membrane liners, since they can absorb de minimis quantities of leachate.[114] This preference tends to isolate the capability of a liner from the rest of the engineered landfill system, its environmental setting, and the persistence and toxicity of the waste it contains.

Furthermore, this preference could inhibit the comparative evaluation of clay and synthetic liners, and overlooks uncertainties about the long-term limitations of any liner material. **A more farsighted approach might require the use of both a synthetic and a compacted clay liner.** The synthetic liner would be used to collect the more concentrated leachate likely to be produced during the operating life of the facility. This would protect the clay liner from the concentrated leachate constituents which can increase the permeability of the clay liner, thus enhancing the long-term integrity of the clay liner backup.[115]

Restrictions on Waste Being Landfilled.—In July 1982, detailed rules were issued defining wastes allowable for landfilling. Treatments are required to mitigate waste characteristics of ignitability, reactivity, and corrosiveness. Incompatible wastes cannot be placed in the same landfill cell. These requirements should greatly reduce the hazards of fires, explosions, and generation of toxic fumes. There are no restrictions against landfilling highly toxic, persistent waste and no treatments are required to mitigate a waste constituent's toxicity or mobility.[116] Containerized liquids cannot be landfilled unless the liquids are rendered not free flowing. Many treatments that can modify the free liquid form do not immobilize toxic constituents. The regulations allow the disposal of free waste liquids into landfills with synthetic liners and leachate collection systems.

Siting Restriction.—The current regulations contain only minimal siting restrictions. For example, they suggest that new landfills should not be sited within a 100-year flood plain, but that if they are, they should be designed to withstand such a flood.[117] Many believe that restrictions should be imposed on sites based on proximity to natural features such as major supplies of ground water used for drinking, designated sole-source aquifers, aquifer recharge areas, sink holes, and wetlands.[118] Such site characteristics are not addressed by the regulations.

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[114] FR 47, No. 143, 32314, July 26, 1982.

[115] David Anderson, geotechnical consultant with K. W. Brown & Associates, College Station, Texas, personal communication, January 1983.

[116] FR 32,366, July 26, 1982.

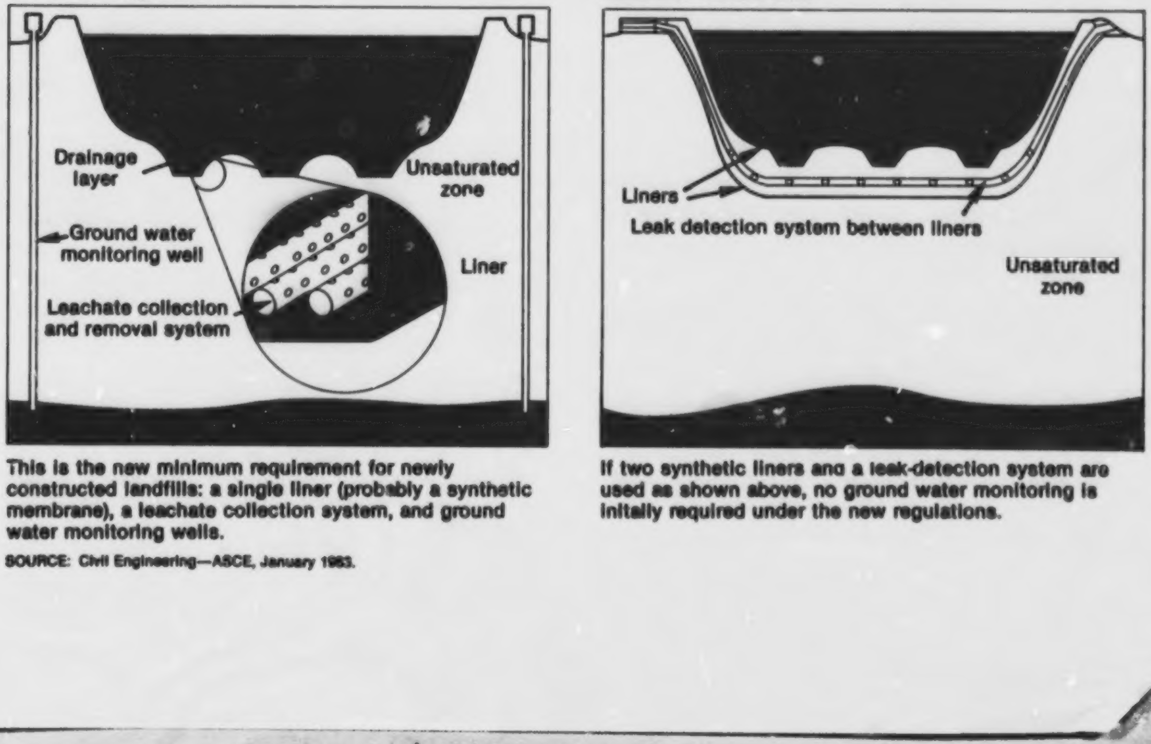
Technology Forcing.—Although EPA is promoting the use of some technologies **in their most advanced form,** less reliable landfilling designs are allowed. Incinerator performance standards have been set close to the limits of their known technical capabilities. Meeting these requirements for routine incineration at many existing facilities will require improvements in engineering design and operation of the facility. However, owners and operators of many existing landfills have already instituted voluntary or State-mandated operating, design standards, and monitoring programs more demanding than Federal requirements, including the use of a double liner.[119]

For landfilling, the regulations establish the **minimum** design requirements for landfill liner system and methods for leachate monitoring—i.e., one bottom liner[*] and external monitoring via ground-water wells for detecting and assessing the effect of leachate migration (see fig. 12). The reliability of this design is inferior to a double liner with a leak-detection system. There is an incentive to promote the use of this more advanced design, through granting an initial waiver of the ground-water monitoring program.

Surface Impoundments

Surface impoundments are depressions in the ground used to store, treat, or dispose of a variety of industrial wastes. They have a variety of names: lagoons, treatment basins, pits,

Figure 12.—Schematic of Single and Double Synthetic Liner Design


Drainage layer
Unsaturated zone
Ground water monitoring well
Liner
Leachate collection and removal system
Liners
Leak detection system between liners
Unsaturated zone

Landfills—single liner

This is the new minimum requirement for newly constructed landfills: a single liner (probably a synthetic membrane), a leachate collection system, and ground water monitoring wells.

Landfills—double liner

If two synthetic liners and a leak-detection system are used as shown above, no ground water monitoring is initially required under the new regulations.

SOURCE: Civil Engineering—ASCE, January 1983.

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[117] Ibid., pp. 32, 290.

[118] David Burmaster, "Review of Land Disposal Regulations," paper submitted to OTA Materials Program, November 1982.

[119] Burmaster, op. cit.

[*] As discussed above, the single liner is likely to be a membrane liner.

and ponds.[120] These depressions can be natural, man-made, lined, or unlined. They can be several feet in diameter or hundreds of acres in size.

Applicability

The majority of wastes put into surface impoundments come from four industrial groups: paper and allied products, petroleum and coal products, primary metals, and chemicals and allied products.[121] These wastes are generally impounded as bulk liquids or sludges.

Surface impoundments are used either to **treat** or **store** industrial wastes. For treatment, surface impoundments are widely used for dewatering sludges, neutralizing and separating waste constituents, and biodegrading waste waters. Storage simply refers to temporary holding. Although estimates of capacity vary, national estimates indicate that there are approximately 1,100 surface impoundments used for hazardous waste, covering a total area of close to 29 million yd^2 (see ch. 4).

Evaluation

Surface impoundments have allowed release of hazardous waste constituents through catastrophic failure, leachate migration, and volatilization of organics. Impoundments are more subject to catastrophic failure than landfills because they tend to contain more bulk liquid. Evidence of surface- and ground-water contamination resulting from impoundments is well documented.[122] This has occurred from sudden releases; e.g., by overtopping the sides, dike failures, or rupture of the liner due to inadequate subgrade preparation, or sinkhole formation.[123] [124] In addition, slow leakage can contaminate soil and ground water. This is especially true for unlined impoundments. Investigations at some unlined "evaporation ponds" have shown that seepage accounted for more of the reduction in volume than did evaporation.[125] In general, these release pathways are addressed by Federal regulations (see also "Technical Regulatory Issues").

There is an expected rate of leakage even through intact liners. Some liquids are chemically aggressive to liners, increasing the rate of movement through the liner. Leakage occurs in much the same manner described in the previous section for landfills. The rate of leakage generally depends on the same factors (see discussion of liners in the "Landfill" section). For impoundments, one primary difference is that there is always a hydraulic gradient acting on the liner. An additional concern is how long the wastes are held in the impoundment before their hazardous characteristics have been mitigated.

Some organic liquids currently being held in impoundments are volatile. Volatilization for many organic chemicals can occur at normal atmospheric temperatures and pressures. This has recently led to investigations of the potential magnitude and severity of organic air emissions.

There is little field data to indicate the magnitude of air emissions from surface impoundments. Most of the information available is from mathematical models that estimate an emissions rate from the many factors influencing volatilization. These include the concentration of organics in the waste, their vapor pressures and solubilities, environmental factors such as air and water temperature, wind velocity, and the surface area of the impoundment.[126] [127]

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[120] D. W. Miller (ed.), *Waste Disposal Effects on Ground Water* (Berkeley, Calif.: Premier Press, 1980), p. 108.

[121] Ibid., pp. 111-129.

[122] See for example, *Final Environmental Impact Statement for Subtitle C, RCRA, 1976*, pt. 1, app. J.

[123] William L. Murphy Rohrer, Senior Environmental Scientist, Pope-Reid Associates, Inc., personal communication concerning ongoing EPA research on failure mechanisms at land-based disposal facilities, January 1983.

[124] J. P. Giroud and J. S. Goldstein, "Geomembrane Liner Design," *Waste Age*, September 1982.

[125] *Surface Impoundments and Their Effects on Ground Water Quality in the United States—A Preliminary Survey*, U.S. EPA, Office of Drinking Water, 570/9-78-004, June 1978.

[126] L. J. Thibodeaux, et al., "Chemical Volatilization Mechanisms From Surface Impoundments in the Absence of Wind," *Land Disposal of Hazardous Waste*, proceedings of the 8th Annual Research Symposium, EPA 600/9-82-002, March 1982.

[127] Thomas T. Shen, "Estimation of Organic Compound Emissions From Waste Lagoons," *Journal of Air Pollution Control Association*, vol. 32, No. 1.

Many of the models were designed to represent other environmental transport phenomenon, e.g., evaporation from oceans or lake basins, and have been adapted for application to organic emissions. Consequently, estimates of emissions derived from these models must be viewed with caution. Nonetheless, the models estimate a significant rate of emissions. For example, emissions from a 1/4-acre impoundment,* holding 100 mg/l benzene and 100 mg/l chloroform, are estimated to be almost 45 lb/hr of benzene and 39 lb/hr of chloroform.[128] This rate of emissions would decline but continue until a covering was installed. Further model development work, including validation sampling, is underway.[129]

Technical Regulatory Issues

The effectiveness of the interim final regulations lies in how well they improve the performance of surface impoundments over past practices. The Federal regulations require that new impoundments have a liner, and establish the minimum design and performance standard; i.e., a single liner intended to meet the narrative performance criteria stating that the liner must "prevent any migration" of waste constituents out of the impoundment during its active life.[130] Although these requirements for liners will reduce leakage, the literal narrative standard is probably technically infeasible. Lining materials have long been used to reduce seepage and economic losses of stored liquids, however the use of liners for pollution control is comparatively new. A great deal of R&D in liner technology will be required to meet these standards. Two researchers state the issue well:[131] [132]

> There is a lack of formalized design procedures to accomplish the objective of pollution control. Because of this lack, there is a tendency toward qualitative approaches to liner design. It is often assumed, for example, that liners are either impermeable or of such low permeability that further analyses are not required. The end result can be failure of the liner to perform as intended.

Similarly:

> . . . in engineering, past practice has frequently meant to assume that fine grained soils are effectively "impervious" and to forego attempts to measure their coefficient of permeability.

The regulatory incentive for installation of double liners with leak-detection systems applies also to impoundments. However, in contrast to leak-detection systems currently used with landfills, OTA found that detection systems placed beneath the primary liner of an impoundment can be used to routinely remove the liquids from between the liners. This reduces the hydraulic pressure from the secondary liner. In some cases, this kind of leachate detection and removal system are already used to remove the liquids expected to migrate through the primary liner.[133] Ground water at sites which are especially vulnerable to contamination would be better protected by this system. Instead, the regulations allow the use of a single liner, and rely on an external ground-water monitoring net to detect waste constituents in excess of ground water standards.

As with landfills, a broad exemption from the requirement for any liner is allowed for existing impoundments. Development of remote-sensing techniques to detect leakage at existing sites has recently begun.[134] EPA is also investigating techniques for retrofitting synthetic liners at existing impoundments.[135] Combining these efforts with information about the characteristics of the site and the waste could reduce reliance on detection monitoring and remedial action.

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*With a depth of 3.5 meters, ambient temperatures of 25° C, and wind speeds of about one-tenth mph.

[128] Ibid., p. 81.

[129] Steve James, Project Officer, Municipal Environmental Research Laboratory, personal communication, January 1982.

[130] FR 32,357, July 26, 1982.

[131] Folkes, op. cit.

[132] R. E. Olson and D. E. Daniel, "Field and Laboratory Measurement of the Permeability of Saturated and Partially Saturated Fine-Grained Soils," Geotechnical Engineering Report GR 80-5, Department of Civil Engineering, University of Texas, June 1979.

[133] Peter Vardy, Waste Management inc., personal communication, January 1983.

[134] Waller and Davis, op. cit., in proceedings of the Eight Annual Research Symposium, EPA 600/9-82-002, March 1982.

[135] John W. Cooper and David Schultz, "Development and Demonstration of Systems to Retrofit Existing Liquid Surface Impoundment Facilities With Synthetic Membrane," in *Management of Uncontrolled Hazardous Waste Sites*, conference proceedings, Washington, D. C., December 1982.

Federal regulations also require that impoundment dikes be designed and constructed to prevent massive failure. In the past, massive dike failure has been linked to damage caused by leakage from the impoundment. The regulatory criteria requires that liner leakage be considered in the design and construction of structurally sound dikes. To the extent that new dikes meet this requirement, sudden releases from impoundments should be reduced. In addition, new impoundments are to be designed to withstand certain storm and flooding events. However, as with landfills, siting requirements are minimal. Furthermore, existing sites are exempted from having to upgrade dikes and berms. In some cases, exempted impoundments may pose substantial risk of sudden releases.

Many of the regulatory requirements pertain to closure and post-closure responsibilities. At closure, impoundment operators have two options: to remove all remaining wastes and contaminated lining material for disposal at an approved RCRA facility or decontaminate, or solidify/stabilize, the remaining waste so that it can structurally support a final cover. If this second option is taken, the impoundment is essentially closed like a landfill, and similar monitoring and maintenance responsibilities apply. Long-term uncertainties related to liner life and cover integrity are similar to those discussed in the landfill section. Issues concerning lack of criteria for what constitutes adequate "stabilization" of the waste are similar to those discussed in landfill pretreatment requirements.

EPA is beginning to investigate the potential for air quality degradation resulting from impounded volatile organics and is planning research to identify appropriate regulation in this area. Some States, notably New York and California, are also investigating this issue.[136] California has suggested both limits on the amount of volatile organic material that can be land-disposed and limiting the time certain wastes can be stored in impoundments as air quality control measures.[137]

Underground Injection Wells

Injection of liquid waste into subsurface rock formations is a technology that uses porous sedimentary strata to hold liquid waste. The pores of all porous rock formations contain liquids, gases, or both. The gas or liquid is contained within the strata under pressure caused by overlying rocks. Internal pressures within strata can vary significantly, depending on the porosity of the formation, its depth, and other physical and chemical factors. Essentially, underground injection entails drilling a well to the depth required to intersect an appropriate geologic formation (known as the injection zone) and pumping the liquid waste in with pressure sufficient to displace the native fluids, but not so great as to cause fracturing of the strata or excessive migration of the waste. Formations suitable for waste injection should meet the following criteria:[138]

- it should not have value as a resource—e.g., as a source of drinking water, hydrocarbons, or geothermal energy;
- it must have sufficient porosity and volume to be able to accept the anticipated amount of liquids;
- it should be sealed both above and below by formations with sufficient strength, thickness, and impermeability to prevent migration of the waste from the disposal zone; and
- it should be located in an area with little seismic activity to minimize both the risk of earthquake damage to the well and triggering of seismic events.

There is no standard injection-well design because design requirements are influenced by site-specific geology. Figure 13 illustrates the design of an injection well that might be used for hazardous waste disposal. As shown in the figure, the well is constructed with three concentric casings: the exterior surface casing, the intermediate protection casing, and the injection tubing. The exterior surface casing is designed to protect freshwater in the aquifers through which the well passes and to protect the well exterior from corrosion. The casing extends below the base of aquifers containing potable water and is cemented along its full length. Similarly, the intermediate protection casing extends down and through the top of the injection zone and is cemented along its full length. The waste is actually transported through the injection tubing, the innermost casing. The tubing also extends into the top of the injection zone; its endpoint is the point of waste discharge. The injection tubing is sealed off from the intermediate casing, creating annular space between the injection tubing and the casing. The annulus is filled with fluid containing corrosion inhibitors to protect the casing and tubing metal. The fluid is pressurized between the sealing at the base of the well and the well head assembly.[139] [140] Since the pressure within the annulus is known, monitoring the pressure during the operation of the well can be a method of checking the integrity of the injection system. Anomalous drops in pressure indicate a leak, either in the injection tubing or in the outer casing.[141]

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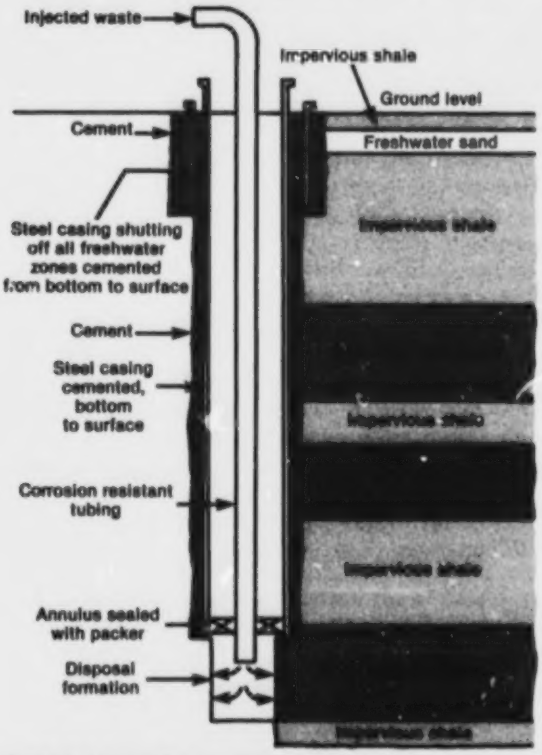
[136] Thomas T. Shen, Senior Research Scientist, New York State Department of Environmental Conservation, personal communication, December 1982.

[137] State of California Air Resources Board, "Suggested Control Measure To Reduce Organic Compound Emissions Associated With Volatile Organic Waste Disposal," August 1982.

[138] Don L. Warner and Jay H. Lehr, *Subsurface Wastewater Injection (Berkeley, Calif.: Premier Press, 1981),* pp. 124-127.

Figure 13.—Schematic of Typical Completion Method for a Deep Waste Injection Well


Injected waste
Impervious shale
Ground level
Cement
Freshwater sand
Steel casing shutting off all freshwater zones cemented from bottom to surface
Impervious shale
Cement
Steel casing cemented, bottom to surface
Impervious shale
Corrosion resistant tubing
Impervious shale
Annulus sealed with packer
Disposal formation
Impervious shale

SOURCE: R. B. Pojasek, *Toxic and Hazardous Waste Disposal*, vol. 4, Ann Arbor Science, 1980.

When injection operations cease, the well is plugged. Proper plugging is necessary to maintain the existing pressure in the injection zone, to prevent mixing of fluids from different geologic strata, and to prevent flow of liquids from the pressurized zone to the surface.[142]

Applicability

Injection wells are capable of accepting a wide range of waste liquids. The primary characteristics of a liquid that limit the applicability of injection well disposal are: high suspended solids content, high viscosity, and chemical incompatibility with either the formation or formation fluids. Before injecting a waste, its chemical characteristics must be compared with the mineral characteristics of the formation and the native fluids within the injection zone to determine their compatibility.[143] Chemical pretreatment of the waste can sometimes make them more compatible with a specific injection zone formation. Examples of waste that can be disposed via injection wells are:[144]

- dilute or concentrated acid or alkaline solutions;
- solutions containing metals;
- inorganic solutions;

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[139] *Waste Age*, October 1982.

[140] Ray W. Amstutz, "Deep-Well Disposal: A Valuable Natural Resource," in *Toxic and Hazardous Waste Disposal*, Robert Pojasek (ed.), vol. 4, Ann Arbor Science, 1980.

[141] Warner and Lehr, op. cit., p. 295.

[142] Ibid., p. 320.

[143] Ibid., pp. 159-177.

[144] Amstutz, op. cit., p. 285.

- hydrocarbons, including chlorinated hydrocarbons;
- solvents; and
- organic solutions with high biochemical or chemical oxygen demand.

Industries using injection wells for waste disposal are listed below in approximate order of predominance:[145]

Industry type	*Percent*
Chemical and allied products	49
Petroleum refining	20
Sanitary service	9
Oil and gas extraction	6
Primary metals	6
All others	10

Current Use

Estimates of the total number of injection wells currently in use are not in agreement. Some variance is due to the definition of injection wells used in conducting well inventories. Uniform Federal definitions for classifying injection wells became final in February 1982. Wells are now categorized into five classes:[146]

1. Class I wells include those used for disposal of municipal or industrial waste liquids and nuclear waste storage and disposal wells that discharge below the deepest underground source of drinking water;
2. Class II wells are those used for oil and gas production;
3. Class III wells include mining, geothermal, and other special process wells;
4. Class IV wells are those which inject hazardous waste into or above an underground source of drinking water; and
5. Class V wells include all others (e.g., irrigation return flows) not in Classes I through IV.

Thus, wells used to dispose of federally defined hazardous liquid waste can fall into one of two classifications, Class I or Class IV. The distinction lies not in the characteristics of the waste injected, but in the discharge point relative to an underground source of drinking water. Class I wells discharge waste beneath the deepest formation containing, within one-quarter mile of the well bore, a drinking water source. Class IV wells are those used to inject hazardous liquids **into** or **above** a formation which, within one-quarter mile of the well bore, contains a drinking water source.

Based on preliminary validation surveys of hazardous waste facility notification requirements, EPA estimates that 159 wells are currently in use for disposal of hazardous industrial liquids; this figure presumably includes both Class I and IV (see ch. 4). Earlier inventories generally indicate a greater number of disposal wells. Better information may become available when all States report their intentions to develop programs under the Safe Drinking Water Act.[147] The total rate of discharge for wells disposing of industrial waste is large. One source estimates that, based on volume, disposal of hazardous waste through injection wells was the predominant disposal method in 1981. An estimated 3.6 billion gallons were injected that year.[148] Information about the hazardous characteristics of these wastes is not available.

The majority of injection wells are located in States with a long history of oil and gas exploration. The geology in these areas is often well-suited for waste disposal zones; moreover, the geological characteristics are well documented because of petroleum exploration. For example, EPA Region VI contains almost 60 percent of the covered disposal wells inventoried in 1975.[149] The majority of these wells (about 58 percent) inject waste into comparatively deep stratum—e.g., at depths between 2,000 to 6,000 ft (600 to 1,800 m). In general, disposal into formations at greater depth are unlikely to contaminate surface or near-surface water. About 30 percent inject waste into formations less than 2,000 ft (305 m). The receiving formations are approximately equally distributed between sand, sandstone, and carbonate rocks.[150] Strata with this type of lithology can be water-bearing. Whether they are considered underground sources of drinking water depends on the quality and quantity of the water they contain and how economically accessible they are. All three factors vary across the Nation.

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[145] Warner and Lehr, op. cit., p. 5.

[146] 47 FR 4902, Feb. 3, 1982.

[147] Jentai Yang, Office of Drinking Water, EPA, personal communication, January 1983.

[148] Part A Universe Telephone Verification, contract No. 68-01-6322, prepared by Westat, Inc., for EPA, November 1982, p. 3.

[149] Warner and Lehr, op. cit., p. 3.

[150] Ibid., pp. 5-7.

Effectiveness as a Disposal Technology

Technologies for constructing and operating wells for waste disposal is well established; much has been transferred from that used for oil and gas exploration. The ability of injection wells to keep waste isolated in the injection zone depends on many site-specific factors, including the well design and expertise of the operator. If a failure occurs, the consequent risk depends on the site geology, characteristics of the waste injected, the extent of the failure, detection of the failure, and whether corrective action is feasible and undertaken. The following list of potential contamination pathways resulting from faulty construction, operation, and/or deterioration of the well are briefly discussed below:[151]

1. injection into or above potable aquifers,
2. leakage through inadequate confining beds,
3. leakage through confining beds due to unplanned hydraulic fracturing,
4. displacement of saline water into a potable aquifer,
5. migration of injected liquids into the potable water zone of the same aquifer,
6. injection of hazardous liquid into a saline aquifer eventually classified as a potable water source,
7. upward migration of waste liquid from the receiving zone along the outside of the well casing,
8. escape into potable aquifers due to wellbore failure, and
9. vertical migration and leakage through abandoned or closed wells in the vicinity.

Some existing disposal wells probably threaten contamination of drinking water sources through the first pathway listed. These are the Class IV wells which discharge waste into or above formations which, within one-quarter mile of the discharge point, are sources of drinking water. The exact number and location of these wells is not known.[152] Federal policy requiring closure of wells discharging into a drinking water source is just beginning to go into effect. There is still no Federal policy for wells injecting **above** a drinking water source (see "Technical Regulatory Issues").

Leakage and migration of waste to a potential water source can result from inadequate confining beds, or unexpected fracturing of a confining bed (pathways 2 and 3 above). Techniques currently used for surveying the hydrogeology of a site prior to construction minimize unintentional breaches of the confining beds. However, if such breaches occur, they can generally be detected during the operating life of the well by monitoring of well-fluid pressures. There are corrective actions available that can potentially reduce the likelihood of contamination resulting from these kinds of failure, but they generally rely on changing the hydraulic gradient within the affected aquifer. Experience with these techniques is limited. Their use is not always possible nor completely effective.[153]

Pathway 4 describes contamination of a potable water source with naturally occurring saline water that does not meet drinking water standards. This could occur if the pressure buildup resulting from waste injection within the receiving zone is sufficient to displace the native fluids into a potable water source. It should be possible to minimize this kind of contamination through careful surveying and selection of the injection zone.

The quality of water contained within an aquifer can vary considerably within a single water-bearing stratum. It is not unusual for the dissolved solids concentration within an aquifer to increase from the top to the bottom of an aquifer. Thus, water drawn from one location may meet drinking water criteria, while water drawn from another location within the same formation may not. Large aquifers that exhibit this range of water quality can and are being used for waste disposal, provided that the discharge point and the estimated radius for waste dispersion remains within the area containing nonpotable water.[154] Pathway 5 describes contamination resulting from unexpected waste migration into the potable water zone. If waste-injection practices increased significantly, this pathway could become more prevalent in the future.[155]

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[151] David W. Miller (ed.), *Waste Disposal Effects on Ground Water* (Berkeley, Calif.: Premier Press, 1980), p. 366.

[152] Yang, op. cit.

[153] William Thompson, Senior Scientist, Geraghty & Miller, Inc., personal communication, November 1982.

Contamination of an aquifer as described in pathway 6 is not a result of poor planning or technical failure. Rather, it could occur in the future as the criteria change for determining what levels of aquifer quality constitute an economical water source. Due to regional differences in the abundance and quality of surface and ground water resources, there are differences in the criteria used to define an underground water source for drinking supplies, agricultural, or industrial use. These criteria could be revised in the future to encompass currently uneconomical or less desirable water sources as increasing demands are placed on available ground water sources.

The potential for waste migration is generally considered greatest in the immediate vicinity of the well bore (pathway 7).[156] Waste can also migrate laterally through a breach in the well bore. This kind of well-bore failure can occur, for example, through corrosion or damage due to subsurface pressures exerted on the well.[157] [158] Migration via these routes can generally be detected through monitoring of fluid pressures both within the well bore and within the annulus if the leakage occurs during the operating life of the well. In the event of leak detection, techniques are available to reconstruct well casings to reduce waste migration.

The contamination pathway described as pathway 9, upward migration of waste through abandoned or closed wells, is particularly insidious because regions where waste injection is widely practiced also have a long history of energy exploration and development. Depending on the site geology, these wells provide vertical connections from deeper formations to near surface or surface formations. Many of these wells were drilled before plugging of abandoned wells was required. Often, their locations are not known and some may no longer be evident at the ground surface. One source estimates that there may be more than 1 million unplugged wells unlocated in North America.[159] To address this concern, current Federal regulations require potential disposers to calculate the subsurface area expected to be affected by the pressure of waste injection. Before new waste injection can begin, the operator is required to survey and to plug existing wells within this area.[160]

Similarly, Federal regulations require that new wells must be plugged at closure to maintain pressure within the injection zone. There are no specific Federal requirements for well abandonment, because the procedures used depend on the well construction and site hydrogeology. Proposed plugging methods are evaluated by individual State-permitting authorities. Wells are plugged by selectively cementing sections throughout its length. There is no technical concensus over the placement of well plugs; their location and extensiveness are determined by State requirements and cost considerations.[161] Some States require that plugs be set over the entire length of the injection zone, and extend 50 to 100 ft into the overlying confining beds. In some wells, injection can occur over hundreds to a thousand feet of formation. In addition, plugs are generally set above and below each aquifer that the well passes through.[162]

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[154] Ibid.

[155] Miller, op. cit.

[156] Warner and Lehr, op. cit., p. 293.

[157] "Mechanical Integrity Testing of Injection Wells," EPA contract No. 68-01-5971, prepared by Geraghty & Miller, Inc., April 1982.

[158] "Technical Manual: Injection Well Abandonment," EPA contract No. 68-01-5971, prepared by Geraghty & Miller, Inc., April 1982.

[159] R. Allen Freeze and John A. Cherry, *Groundwater* (Englewood Cliffs, N.J.: Prentice Hall, Inc., 1979), p. 455.

[160] 40 CFR 146.6 and 146.7.

[161] "Technical Manual: Injection Well Abandonment," op. cit., p. 6.

[162] Ibid., pp. 5, 6.

Although there is considerable documentation of well abandonment in the oil and gas industry, there is less information regarding potential problems with waste disposal well abandonment.[163] [164] In 1973, the State of Michigan surveyed 20 abandoned wells to determine the adequacy of the plugs. The wells were redrilled to verify the position and condition of the cement plugs. Some plugs were never found; others had deteriorated and were soft.[165] More advanced well-plugging techniques should improve this record. Installation of effective plugs requires careful planning and considerable operator skill.[166] There is little experience with abandonment of waste disposal wells on which to evaluate the long-term integrity of well plugs.

There is currently little information about contamination incidents resulting from injection well practices for all classes of wells. Moreover, it is sometimes difficult to correlate a particular contamination incident with a specific well disposal practice. Past documentation of contamination has been attributed to a variety of injection well operations. For example, one survey conducted by the State of Texas between the years 1967 and 1975 reviewed 800 wells that had been used for oil and gas production. The wells were located by reports of water wells becoming contaminated with brackish water, of wells flowing at the ground surface, or by field investigations.[167] Research is underway to better define the correlation between ground and surface water contamination related to injection wells.

In addition to monitoring pressures within the well, there are several types of monitoring wells that can provide information on the effects of waste injection. Constructing monitoring wells in the receiving formation is the only direct method of detecting the rate and direction of waste liquid movement. However, sampling from the receiving formation has the disadvantage of providing additional routes for contaminant migration.[168] Monitoring wells can also be constructed to sample from the confining beds or from aquifers above the injection zone. The usefulness of such wells may be limited by site-specific factors. There are cases, however, where monitoring wells sampling immediately above a confining bed have detected contamination from leakage which was not detected by monitoring well pressures. Also, the injection well itself can be adapted to monitor overlying aquifers.[169] State requirements for types and locations of monitoring wells vary.

Federal standards for Class I wells require that operators report "the type, number and location of wells" used to monitor pressures and migration of fluids into underground sources of drinking water, the frequency of sampling, and the parameters measured (40 CFR 146.13). These requirements are just now going into effect for States with approved programs. Currently, much of the direct sampling for contamination is conducted through water wells that are part of the facilities water supply system or which are near an injection site.[170]

Technical Regulatory Issues

All classes of injection wells are regulated by the Underground Injection Control (UIC) program under the Safe Drinking Water Act (SDWA). Wells which inject liquid hazardous waste are regulated under both SDWA and RCRA. Because of this overlapping jurisdiction, injection-well facilities that are in compliance with a UIC permit and which meet general requirements for notification, manifesting of waste, annual reporting, and closure certification, will be considered to have a RCRA permit (F.R. 47, July 26, 1982, 32281). Requirements for financial responsibility, post-closure care and corrective action responsibility have not yet been specified.

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[163] Ibid., p. 1.

[164] Warner and Lehr, op. cit., p. 321.

[165] "Technical Manual: Injection Well Abandonment," op. cit., p. 9.

[166] Ibid., p. 8.

[167] Kerr S. Thornhill, Environmental Laboratories, Ada, Okla., personal communication, January 1983.

[168] Warner and Lehr, op. cit., pp. 310-311.

[169] Ibid., p. 312.

[170] Thornhill, op. cit.

Further, the development of UIC standards is not complete. Specifically, there are no standards for Class IV wells that inject wastes **above** a drinking water source (F.R., ibid.). States with approved programs are required to eliminate waste disposal through a Class IV well injecting **into** a drinking water source within 6 months of receiving approval. To date, only nine States have approved UIC programs, although several more are currently being reviewed.[171]

Corrective measures are required if a failure occurs during the operating life of the well. UIC regulations require the installation and use of continuous recording devices to monitor injection pressure, annular pressure, waste volume, and flow rate.[172] In addition, the well must be tested for mechanical integrity through a temperature or noise log test at least once every 5 years.[173] If a significant leak is detected, the well casing must be repaired or replaced.[174] Closure of the well must be certified.

In general, waste disposal through properly constructed and operated injection wells into deep formations below the lowest drinking water source are **much less** likely to contaminate surface or shallow aquifers than are landfills and surface impoundments. There do not appear to be requirements for corrective action for damage that **might** occur after well closure comparable to the requirements imposed on land-based disposal under RCRA. The Post-Closure Liability Trust Fund Act will provide funding for site maintenance and care, as well as a source of compensation for personal and property damage. However, it is unclear how the tax will be calculated for liquid waste injected into disposal wells.[175] The statutory language specifies that the tax be levied at a rate of $2.13 per dry weight ton of hazardous waste delivered to an RCRA permitted facility.

Comparative Unit Costs for Selective Technologies

There is little consistent information available about the costs necessary to achieve a given level of control by waste treatment and disposal practices. This is due to a variety of factors: 1) lack of consensus about what constitutes comparable levels of control across technology alternatives, 2) the regulatory uncertainties of the evolving Federal program, 3) cost information that is generally specific to an application of a particular technology to a particular waste, and 4) the dynamic nature of costs as industry gains experience in responding to the regulatory requirements.

Almost all the studies that evaluated costs for different treatment and disposal alternatives considered the effect of the new RCRA regulations. Although tentative, given the lack of experience of the interim final regulations, virtually all the studies point out two trends:

1. the post-closure, liability, and corrective action requirements will have a greater effect on land-based disposal options relative to treatment or incineration, and
2. the costs for any treatment option is affected by the waste type. Costs are most sensitive to waste characteristics for chemical and thermal destruction and less sensitive for landfills.

While cost data are scarce and only roughly comparable in general, those that reflect differences in waste form are even fewer. For example, fee schedules for commercial facilities that provide several treatment steps and final disposal are frequently determined after testing samples of the prospective waste stream. Rather, most of the economic studies completed to date have focused on the incremental cost increases—e.g., in administration, recordkeeping, security, personnel—required by RCRA regulations. Another very important economic lever that has been studied in detail is the effect of the liability requirements on the decisions made by treatment and disposal facility operators. This is because the liability and insurance requirements reflect, to a limited extent, the perceived sudden and non-sudden risks associated with types of waste treatment or disposal, facility designs, and operating practices.

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[171] Yang, op. cit.

[172] 40 CFR 146.13.

[173] 40 CFR 146.8 and 146.13.

[174] Yang, op. cit.

[175] Eric Nagle, Environmental Law Institute, personal communication, November 1982.

This section presents a brief comparison of technology costs. All unit cost figures should be considered as approximate. Their usefulness is in general comparison. Costs were derived from three sources; all have limitations:

1. The Commerce study figures are based on treatment costs in the Great Lakes Region only. Unit costs are based on surveys of actual charges levied for wastes from three industry sectors. The surveys requested that the respondents factor their expectations of the increased costs of the interim status, not interim final, Federal requirements.
2. The EPA study, completed under contract by Booz, Allen & Hamilton, reports unit costs based on a survey of the nine largest commercial facilities. In 1980, these facilities treated an estimated 51 percent of the total national waste stream which was handled offsite, estimated at 3.7 million tons. The unit costs reported may be slightly overstated relative to the costs incurred by a generator with onsite treatment and disposal facilities because these are prices charged to return an investment on a commercial service.
3. The cost figures reported in the California Air Resources Board study are based on surveys of commercial and onsite facility operators.

Table 34 presents costs by type of waste management used and general description of waste type. Table 35 presents a limited comparison of unit costs for treatment v. incineration for selected waste types. Table 36 presents a limited comparison of landfill and thermal destruction costs and illustrates the effect of waste form and waste type on these costs.

As illustrated in table 36, the cost for commercial landfill service ranges from between $55 to $240/tonne. This range covers the gamut from low-risk bulk waste to more hazardous drummed waste. These designations of hazardous characteristics are based largely on qualitative assessments. By comparison, the range of costs for commercial incineration is $53 to $791/tonne. This range of costs also reflects the relative technical ease of destroying comparatively clean combustible liquids as contrasted with highly toxic refractory solids and drummed wastes.

Table 34.—Comparison of Quoted Prices for Nine Major Hazardous Waste Firms in 1981[a]

Type of waste management	Type or form of waste	Price 1981	$/tonne[b] 1981
Landfill	Drummed	$0.64-$0.91/gal ($35-$50/55 gal drum)	$168-$240
	Bulk	$0.19-$0.28/gal	$55-$83
Land treatment	All	$0.02-$0.09/gal	$5-24
Incineration clean	Relatively clean liquids, high-Btu value	$(0.05)[c]-$0.20/gal	$(13)[c]-$53
	Liquids	$0.20-$0.90/gal	$53-$237
	Solids, highly toxic liquids	$1.50-$3.00/gal	$395-$791
Chemical treatment	Acids/alkalines	$0.08-$0.35/gal	$21-$92
	Cyanides, heavy metals, highly toxic waste	$0.25-$3.00/gal	$66-$791
Resource recovery	All	$0.25-$1.00/gal	$66-$264
Deep well injection	Oily wastewater	$0.06-$0.15/gal	$16-$40
	Toxic rinse water	$0.50-$1.00/gal	$132-$264
Transportation		$0.15/ton mile	

[a] Interviews were conducted in May of 1980 and February of 1982.
[b] Factors used to convert gallons and tons into tonnes are described in the appendix.
[c] Some cement kilns and light aggregate manufacturers are now paying for waste.

SOURCE: Booz, Allen & Hamilton, Inc.

Table 35.—Incineration v. Treatment: Range of Estimated Post-RCRA Charges for Selected Waste Types

	Costs per tonne	
	Incineration	Treatment
Waste oils	$94	$40
Paint sludges	453	94
Nonchlorinated solvents	94	61
Chlorinated solvents	206	161
Cyanides	211	297

NOTE: Cost estimates are based on surveys of commercial treatment and incinerator facilities in the Great Lakes regions. Costs reported reflect the surveyed industries estimates of their charges based on compliance with RCRA regulatory requirements for *Interim Status* facilities. No specific information provided about type of process or incinerator used, or characteristics of waste residuals.

SOURCE: Office of Technology Assessment, from Hazardous Waste Management in the Great Lakes Region, Department of Commerce, September 1982.

In cases where a waste can be easily detoxified, or energy value recovered, unit costs for treatment or incineration can be lower than unit costs for landfilling. At the low end of the cost range, unit costs for particular wastes can be roughly comparable. It is at the high end of the spectrum where unit costs diverge greatly between the landfill and the incineration alternative. For example, incineration of solid or drummed waste costs in the range of about $400 to $800 per tonne as compared with about $170 to $240 per tonne for landfill disposal.

Midrange unit costs for land disposal of undifferentiated bulk waste and roughly designated waste hazard classes range from about $55 to $83 per tonne. These costs are comparable to the unit costs for various waste treatment processes (table 35), which range from about $34 to $260 per tonne, depending on the waste type. Unit costs for thermal destruction of waste fall generally at the upper middle range, e.g., generally between about $100 to $400 per tonne, although specific costs can be much greater or much lower. In particular, OTA found that emerging thermal destruction techniques may be less expensive than conventional incineration techniques (see "Emerging Thermal Destruction Technologies").

Available information on waste disposal clearly indicates that land-based disposal is currently the predominant waste disposal method. Landfill costs are generally less than costs for treatment and incineration and there continues to be great debate about whether these lower costs include all the costs of landfilling. Some of the cost differences depend on factors such as the capital required to implement technology, whether it is being operated for commercial or private purposes, and personnel requirements. These are all factors affecting the cost of any technology option.

More specifically, the essence of the debate concerns the extent to which the still unfolding Federal regulatory policy affects market decisions for selection of waste technology. The current Federal program requires that all facility operators demonstrate financial assurance for closure and post-closure care, and that they carry liability insurance. The estimated costs of these requirements for specific facility types are discussed in chapter 7. Note that the costs to meet these requirements are expected to be greater for landfills and surface impoundments than for incinerator facilities. Some contend that current Federal policy favors the land disposal alternative; others that the financial assurance requirements and the insurance re-

Table 36.—Unit Costs Charged for Services at Commercial Facilities

	Landfill	$/tonne	Incineration	$/tonne
Form:	Drum	$168-$240	Drummed	$120-$400
	Bulk	$55-$83	Liquids	$53-$400
Type:	Acids/alkalis	$13-$120	Relatively clean liquids with high-Btu value	$(13)[a]-$53
	Odorous waste[b]	30	Liquids	$53-$237
	Low risk hazardous waste: (e.g., oil and gas drilling muds)	$13-$29	Solids and/or highly toxic liquids	$395-$791
	Hazardous	$30-$80		
	Extremely hazardous	$50-$140		

[a] Hazard designation based on California's classification system.

[b] Some cement kilns and light aggregate manufacturers pay for these comparatively clean, high energy value wastes.

SOURCE: Office of Technology Assessment; compiled from Booz, Allen & Hamilton, quoted prices from nine major waste management firms, 1981 and from the California Air Resources Board, August 1982.

quirements are sufficient to correct imbalances between current and future costs for facility operators. Demonstration of financial capability for corrective action that may be necessary in the future at landfills and surface impoundments is not currently required by the Federal regulatory program, although the issue is being considered. Corrective action costs are estimated to be greater than the present value cost of either financial assurance for post-closure maintenance or liability insurance. Moreover, these corrective action costs are annual expenditures. Actual field data about the time required to mitigate contamination to an aquifer are limited, but estimates are generally on the order of many years. Thus, demonstration by a facility operator of financial capability to mitigate potential ground-water contamination could have a greater economic effect on the facility operator than the financial or liability insurance requirements currently in place.

It should be noted that transportation costs to waste management facilities can be quite substantial, with long distances increasing direct costs by as much as 50 to 100 percent. In some locations, there may be no near alternatives to land disposal, and the added cost for transportation makes land disposal even more attractive economically. Also, the smaller the quantity of waste handled, the greater the per unit treatment or disposal costs. There are, however, new commercial enterprises aimed particularly at the small generator market, and various techniques can be used to reduce handling costs, including using trucks that deliver chemical feedstocks to pick up carefully labeled and separated hazardous waste.

Ocean Disposal and Dispersal

Early in the 1970's, concern was expressed about the rapidly increasing quantity and variety of material that was being disposed in oceans. During hearings on the Marine Protection, Research and Sanctuaries Act of 1972 (MPRA) testimony before Congress emphasized the fragile nature of the marine environment and our lack of knowledge about effects of ocean waste disposal on human health and ocean organisms. With passage of MPRA, the ocean was given the status of a "last resort" disposal option, to be considered only after other alternatives had been exhausted.

Ten years later, controversy about the appropriate level of ocean protection and use continues. A new understanding of potential environmental risk resulting from land disposal practices has led some to reconsider the ocean as a disposal medium. Interest in using oceans for hazardous waste management has increased as the volume of waste, land disposal costs, and opposition to land disposal sites have increased. Even some dedicated proponents of ocean protection acknowledge that the ocean has a role, albeit limited, in waste disposal management, if there are assurances that ocean resources, especially fish, are protected from destruction or from being made toxic to humans. Certain types of wastes may be better suited for ocean disposal than others. For the most part, however, current scientific information will not resolve uncertainties.

Current Usage

After passage of MPRA, control over ocean disposal became apparent by decreases in the volume (5 million tons in 1973 to 3 million in 1980) and decreases in approved disposal permits (332 in 1973 to 26 in 1980). Currently, ocean disposal in the United States involves the following types of material:

1. **The disposal of material produced by dredging activities necessary to keep the Nation's ports and harbors operating.**[176] Under regulations established by the U.S. Army Corps of Engineers, dredge spoils

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[176] Lee Martine, "Ocean Dumping: A Time to Reappraise?" Issue Brief No. Ib81088, prepared for the Library of Congress, Congressional Research Service, 1982.

are transported by ship or barge to sites approved by EPA. These materials account for an estimated 80 to 90 percent of all U.S. waste deposited in the ocean and for the most part would not be considered hazardous under the RCRA definition. In 1981, it was estimated that only 5 percent of this type of material would be considered hazardous using bioassay techniques.[177]

2. **Sewage sludge produced by municipal secondary treatment plants.** In New York and New Jersey, sludge waste is transported daily by ship or barge to an EPA-approved site in the New York Bight. The volume of waste disposed in the Atlantic Ocean has increased. These wastes could contain variable quantities of toxic constituents and pathogens that would pose hazards to the marine environment and public health.
3. **The discharge of municipal waste and some industrial waste through pipelines to ocean outfalls.** This activity is regulated by EPA under the Federal Water Pollution Control Act of 1972 (FWPCA). Waste disposal through ocean outfalls is a practice used in Boston, on the west coast, in Hawaii, and in Alaska. Along the southern California coast, for example, 30 outfalls discharge an estimated 4.5 billion liters of sewage and sewage sludge daily.[178] As of January 1981, there were 232 land-based dischargers whose outfalls entered the territorial sea and beyond; 74 of these were from industrial sources. This material can pose hazards.
4. **The disposal of acids.** This activity occurs at three EPA-approved sites off the east coast and Puerto Rico. Due largely to efforts to recycle acids, the volume of this industrial waste decreased by 49 percent between 1973 and 1979. Of 150 industrial ocean disposal permits that existed in 1973, only 13 remained in April 1979.[179] Acids can be considered as suitable waste for ocean disposal since they can be neutralized through the large buffering capacity in the marine environment. The mode of discharge, from a barge or vessel, is designed to maximize the initial dispersion and dilution in seawater; there is usually little density difference between the waste plume and the surrounding surface water after the initial few seconds. Acid wastes are almost immediately neutralized by seawater.
5. **Marine incineration of toxic waste aboard specially designed vessels.** This is not really ocean disposal, but rather thermal destruction of organic material at sea. Within the United States, experience has been limited primarily to experimental "burns" involving organic chloride waste, Agent Orange, and, most recently, PCBs.[180] Constraints on this method are discussed in the previous section on thermal destruction.

Legislative Background

The belief that ocean dumping was threatening both the value of the marine environment and human health led to national and international measures to limit, if not prevent, the continued use of the ocean for disposal of waste. Such measures included:

1. MPRA;
2. the Convention of the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, known as the London Dumping Convention, ratified by the United States in 1974; and
3. FWPC, which regulates waste discharges within territorial seas.

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[177] National Advisory Committee on Oceans and Atmosphere, "The Role of the Ocean in a Waste Management Strategy," A Special Report to the President and Congress (Washington, D.C.: U.S. Government Printing Office, 1981).

[178] A. J. Mearns, "Ecological Effects of Ocean Sewage Outfalls: Observations and Lessons," *OCEANUS*, vol. 24, No. 1, 1981, pp. 44-54.

[179] P. W. Anderson and R. T. Dewling, "Industrial Ocean Dumping in EPA Region II—Regulatory Aspects," in *Ocean Dumping of Industrial Wastes*, B. H. Ketchum, D. R. Kester, and P. K. Park (eds.) (New York: Plenum Press, 1981).

[180] K. S. Kamlet, "Ocean Disposal of Organochlorine Wastes by At-Sea Incineration," in *Ocean Dumping of Industrial Wastes*, B. H. Ketchum, D. R. Kester, and P. K. Park (eds.) (New York: Plenum Press, 1981).

The EPA has responsibility to regulate ocean disposal so as:

> . . . to prevent or strictly limit the dumping into ocean waters of any materials which would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities (Public Law 92-532).

The disposal of certain specific wastes (including nuclear materials and most biological and chemical warfare agents) is prohibited, and ocean disposal of other types of waste may be considered only after all alternatives have been exhausted. Although the Army Corps of Engineers has the responsibility for disposal of dredge spoils, EPA was given the authority to approve all disposal sites, including ocean, land, and wetlands.[181]

EPA is directed to establish criteria for review of ocean-disposal permit applications. In establishing or reviewing these criteria, the EPA Administrator is required to consider at least nine factors specified in MPRA, six are related to the effects on human health and the environment, two relate to the availability and effects of alternative methods of disposal, and one designates appropriate ocean sites.

The system established by EPA provides four classes of ocean disposal permits:

1. general permits for the disposal of relatively innocuous waste;
2. special permits for waste that would not "unreasonably degrade" the marine environment, as determined by the types and concentrations of constituents present;
3. interim permits, generally conditioned on an agreement to phase out the particular dumping activity; and
4. emergency and research permits.

Only when reviewing interim permit requests will EPA take into account the need for disposal of a specific waste and the limitation of land-based alternatives.

In 1977, congressional concern centered on the progress being made in phasing out the dumping of sewage sludge in the ocean. Thus, amendments adopted that year gave legislative force to EPA's regulatory effort to impose an absolute ban on all ocean disposal of sewage sludge after December 31, 1981. The regulations implementing this ban were challenged, however, by New York City, which sought an extension of its interim permit to dispose of sludge in the New York Bight. The U.S. District Court for the Southern District of New York ruled in favor of New York City. The Court required EPA to give New York City an opportunity to present evidence indicating that disposal of its waste in the New York Bight had "relatively inconsequential effects" and that land disposal of this material might prove far more harmful to the environment and human health.[182] EPA was required to consider "all statutory factors relevant to a reasoned determination," including the costs and dangers of land-based disposal. EPA did not appeal the decision and is now in the process of developing new regulations to replace those that were invalidated by the Court.

Controversy Over Ocean Use for Hazardous Wastes

Arguments in Favor of Increased Ocean Disposal

Experience and research data obtained over the past 10 years and still being accumulated contribute to the debate regarding appropriate use of oceans in waste management. Arguments in favor of greater use conclude that the marine environment has the capacity to assimilate hazardous constituents. **The assimilative capacity may be defined as the amount of a particular material that can be contained within a body of seawater without producing an unacceptable impact on living organisms or nonliving resources.**

A recent scientific assessment supporting this conclusion was reported by the Regional Seas Program of the United Nations Environmental Program.[183] The results of the 4-year study suggest that oceans are able to assimilate toxic substances in most areas without extreme disturbance of the ecosystem. In addition, a number of scientists report that the ocean has a self-cleansing ability that would enable it to absorb waste without unacceptable consequences.[184]

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[181] William L. Lahey, "Ocean Dumping of Sewage Sludge: The Tide Turns from Protection to Management," *Harvard Environmental Law Review*, vol. 6, No. 2, 1982, pp. 395-431.

[182] Ibid.

[183] Webster Bayard, "World's Oceans Became Cleaner Over the Last Decade, Study Shows," *The New York Times*, Nov. 7, 1982, p. 28.

There is evidence that, in some instances, the marine environment can recover within a few years from pollution previously perceived as heavy.[185] [186] Studies of the outfalls in coastal areas suggest that short-term effects of sewage on marine plant and animal communities do occur. However, over the long-term these communities appear to have the ability to recover. For example, when discharge was initiated at the Orange County outfall in 1972 (at a depth of 60 m), it took a full year for fish and benthic infaunal communities to show adverse effects. Conversely, after cessation of 15 years of continuous discharge at another site (a depth of 20 m):

> . . . the infauna changed from deposit-feeding-dominated communities to the normal, suspension-feeding-dominated communities within three to six months. Copper concentrations in sediments returned to background within a year; trawl catches of bottom fish also decreased, relative to background, within one to two years of discharge termination.[187]

Similar recovery was evident at the sewage sludge site previously used by the City of Philadelphia.[188] Two years after disposal was terminated:

> . . . bacteria and virus levels had declined sufficiently for the Food and Drug Administration to lift restrictions on shellfishing.

Such responses, however, depend on the physical, biological, and chemical characteristics of the sites. For example, sites in the New York Bight have poor dispersion capability, high susceptibility to deterioration of ecosystem conditions (e.g., oxygen depletion), and accumulation of persistent chemicals in marine sediment. In contrast, a site 106 miles offshore from New York City does have dispersion capabilities. Disposal of sewage sludge at this site might enable natural biological and chemical processes to incorporate sludge without detrimental effects.

These somewhat positive experiences with the disposition of constituent fate and their effects have bolstered the cause for greater use of the ocean in waste management. However, these experiences, for the most part, have little relevance to most hazardous waste. Some scientists argue that effective plans can be developed for disposal of highly toxic substances without endangering public health.[189] It is argued that information on marine pollution gained during the past 30 years provides a basis for developing models that can be used to determine the assimilative capacity of coastal waters. Supporters contend that, as more information accumulates about life processes in the ocean, it should be possible to identify pollution problems and formulate remedial actions.

Arguments Against Increased Ocean Disposal

While few would maintain that oceans should be completely excluded from waste disposal, there are arguments against increased use of the marine environment in waste management. **The ocean's status as a global commons makes it more vulnerable to misuse.** The "not in my backyard" attitude that works to block siting of land-based waste facilities does not exist for the ocean. Economics also emphasize this vulnerability. While prodisposal forces cite the growing differential between land and ocean disposal, it is pointed out that there is virtually no cost for an ocean site itself; thus that option will always be cheaper than land-based alternatives.

The suggestion that managers now have adequate data and reliable models to predict and understand the effects of dumping in the ocean also is disputed. The argument that current data show that impacts of disposal are less than anticipated 10 years ago is criticized on the basis that research efforts have not been sufficiently sophisticated to provide sound evidence.

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[184] Lahey, op. cit.

[185] Mearns, op. cit.

[186] W. Bascom, "The Effects of Waste Disposal on the Coastal Waters of Southern California," *Environ. Sci. & Techn.*, vol. 16, No. 4, 1982, pp. 226A-236A.

[187] Mearns, op. cit.

[188] Lahey, op. cit.

[189] E. D. Goldberg, "The Oceans as Waste Space: The Argument," *OCEANUS*, vol. 24, No. 1, 1981, pp. 2-9.

The usefulness of existing models for assimilative capacity is also questioned. Such models attempt to describe the ocean's ability to achieve acceptable levels of concentration and distribution of hazardous substances. A number of weaknesses have been noted:[190]

1. the lack of empirical data, limiting efforts to estimate appropriate concentrations of hazardous contaminants;
2. the lack of information on long-term fate of constituents and effects on the marine environment;
3. only single constituents are considered, ignoring any synergistic effects and thus, possibly underestimating damage to the environment; and
4. uncertainties about the relationship between amounts of waste deposited and the environmental response; unanticipated delayed responses can result in serious underestimation of environmental impacts.

It has been suggested that the assimilative capacity concept is useful as an organizing principle.[191] If it is used to focus research and monitoring on relevant questions, the concept is beneficial. It can also be valuable in defining the lower limits of accepted environmental concentrations in the marine environment. Critics argue, however, that assimilative model assessments cannot, now or at any time soon, serve as a sufficient basis for predicting the hazard potential of persistent substances in the marine environment. A particularly important criticism is that such modeling may not reveal delayed concentrations of toxic substances in surprising places and ways.

There is a belief that the assimilative capacity concept is already failing.[192] Assessments of single-constituent effects will not provide sufficient information; there are hazardous constituents existing in various forms being released in combination at different locations. A solution suggested by critics would be to develop closed systems that would eliminate any release of hazardous compounds from any disposal medium to the environment. With this approach:

> . . . the costs of managing, including recovering or storing or detoxifying wastes, are appropriately assigned to the products of the industry, not diffused as a general cost onto the public at large.[193]

Proponents of continued strict limits on ocean disposal do not suggest that the oceans should be inviolate. The value of multimedia management is recognized, but initial comparisons of the environmental merits of the various options are necessary. Once the medium of choice is determined, other relevant factors, including economics and technological feasibility, should be considered. There is clearly more support for using the oceans for the less hazardous, biodegradable (and less controversial) waste than for substances such as PCBs.

Effective management of ocean-disposal activities should be preceded by a thorough understanding of the fundamental biological, chemical, and physical processes in the marine environment. While such understanding has improved significantly during the past 10 years, particularly for deep-ocean waters, little or nothing is known about the long-term fate of these wastes "or the capacity of these pelagic oceanic regions to assimilate wastes without detrimental effects."[194] Particularly, there is a need to improve the assessment of the biological effects of pollutants in the marine environment. **Current information, therefore, shifts the burden to potential users of the ocean to document and defend such use.**

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[190] Lahey, op. cit.

[191] K. S. Kamlet, "The Oceans as Waste Space: The Rebuttal," *OCEANUS*, vol. 24, No. 1, 1981, pp. 10-17.

[192] G. M. Woodwell, "Waste Disposal: Time for a New Approach," adapted from remarks made before joint meetings of the American Geophysical Society and the American Society for Limnology and Oceanography, San Antonio, Tex., Feb. 17, 1982.

[193] Ibid.

[194] D. R. Kester, B. H. Ketchum, and P. K. Park (eds.), "Future Prospects of Ocean Dumping?" in *Ocean Dumping of Industrial Wastes* (New York: Plenum Press, 1981), pp. 505-517.

Future Research and Data Needs

This reassessment of the ocean's potential for waste disposal comes at a time when there are growing limitations on and increasing problems with land-based methods. More recent legislation than MPRA—i.e., SWDA and RCRA—have imposed new and stringent regulation on land-based disposal of waste. Well-publicized incidents such as the Love Canal have caused public acceptance of landfills and other waste disposal facilities near residential areas to plummet. It is recognized that the high probability that land-disposal activities might decline during the 1980's, may increase interests in ocean-waste disposal.[195] A Federal program is needed that would emphasize research and monitoring **before** allowing disposal of the most hazardous waste in various oceanic environments.

Because of the high value placed on marine biota as a resource, "the biological consequences of ocean dumping are generally regarded as establishing the acceptable limits of waste disposal in the marine environment." Thus, determining what biological parameters should be measured is seen as a major scientific problem. The International Council for the Exploration of the Seas identified four classes of data needs:

1. Bioassay measurements, ranging from determination of lethal concentrations for particular organisms to changes in growth rates brought about by various concentrations of a waste. Where possible, more extensive tests should address synergistic effects of multiple contaminants.
2. Physiological techniques for measurement of growth, scope for growth, and feeding rates—considered the best techniques for assessing biological effects of contaminants on fish, crustaceans, polychaetes, and mollusks.
3. Biochemical measurements, such as reproductive biochemistry, hormone metabolism, and blood-chemical analyses.
4. Ecological assessments—the most direct and comprehensive approach to determining effects of constituent, but difficult to implement.

Several programs are available for obtaining these types of data and include EPA's discharge permit program (characterized as a load-assessment approach), the baseline studies program of the Bureau of Land Management (trend-assessment approach to identifying impacts), and the National Marine Fisheries Service strategy to assess the "health" of fisheries resources on the basis of periodic environmental measurements of selected parameters.

Past experience in "crisis response" may provide useful information for considering ocean disposal of hazardous waste.[196] Identification of common factors in environmental crises concerning mercury poisoning and contamination by DDT, PCB, and Kepone, if recognized and considered in future monitoring strategies, could lead to earlier warning of adverse impacts from ocean disposal. In each of these examples, there was a lack of understanding of the movement of the contaminant in the marine environment and of sensitive organisms or critical factors leading to the observed impact. Thus, future monitoring should be designed to consider fate of constituents and to identify the sensitive points in the ecosystem for each constituent of concern.

Certain types of waste may be better suited for ocean disposal than others.[197] Water and air are dispersal media, whereas land is a containment medium. Waste management should consider whether a persistent toxic material is best disposed in a dispersal or a containment medium. For persistent synthetic chemicals, such as PCBs, Kepone, and DDT, isolation and containment or destruction to the fullest extent possible may be preferred to ocean disposal. For persistent, naturally occurring materials, such as heavy metals and petroleum hydrocarbons, a reasonable argument might be that dispersal is sensible. However, large or continuous additions of even such materials can produce harmful departures from background levels, particularly on a localized basis. **For certain amounts of nontoxic or biodegradable materials, the assimilative capacity of specific ocean locations may be adequate. Acids, alkalis, and nutrients are examples. A management philosophy aimed at maximizing dispersal of such materials, while avoiding disruption of local ecological systems, might be most sensible.**

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[195] National Advisory Committee on Oceans and Atmosphere, 1981, op. cit.

[196] Kester, op. cit.

[197] K. S. Kamlet, "Constraints on the Ocean Dumping of Hazardous Wastes," prepared for presentation at the Northeast Conference on Hazardous Waste, Ocean City, N.J., 1982.

When considering possibly acceptable ocean-disposal activities, it is also necessary to consider the various advantages and disadvantages of different sites. For example, shallow, continental-shelf waters offer the advantages of being better understood, based on experience and scientific research, requiring low-to-moderate transportation costs, and a localization of potential detrimental effects.[198] On the negative side, the resource value of these areas is typically greater. There also is a tendency for substances to accumulate in bottom-living organisms and sediments in these locations. Deep-ocean waters, on the other hand, offer the advantage of broader dispersion and dilution of waste and reduced conflicts with other marine resources. Disadvantages include uncertainties about the ultimate fate and effect of waste, with potential large-scale impacts, and a likely greater effect on planktonic and bottom-living organisms.

Technical Regulatory Issues

It is recognized that a number of important issues should be resolved before proceeding with widespread or indiscriminate use of the oceans for hazardous waste management. Thus, a current study recommends that:

> Before it is too late and major investments are made which may tie us into a long-term commitment, it would be best to:
> 1. test predictions against field experiments;
> 2. develop a waste management plan for coastal areas which considers effects of all pollutant sources;
> 3. design delivery systems which will minimize environmental degradation;
> 4. continue to work on developing pretreatment techniques that will permit waste material to be considered as a resource rather than a waste.[199]

Scientists must determine what additional information is needed to evaluate oceanic discharge under the condition that oceanic resources must be maintained in renewable states and threats (even if long term) to human health are minimized. What are the long-term effects of the very low levels of constituents in the sea? What are the synergistic and antagonistic effects of collectives of constituents? While both general and specific stress indicators are available, such as those for metals and petroleum components, there remains a need to identify specific indices applicable to individual or classes of constituents. Work should be done to compare alternate ocean-disposal strategies, such as dispersing waste above or beneath the thermocline.[200] Federal actions that should precede any widespread movement to use oceans for hazardous waste management include:[201]

1. assessing the state of pollution in U.S. coastal and deep-ocean waters;
2. precisely defining present standards and criteria in terms of specific constituents and regional bodies of water;
3. developing an information system to routinely report what has been learned;
4. coordinating all research to achieve the maximum results from limited research funds;
5. implementing a cost-effective network of coastal water-quality monitoring;
6. simplifying regulatory procedures; and
7. continuously evaluating and reevaluating water-quality standards.

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[198] Kester, op. cit.

[199] R. L. Swanson and M. Devine, "The Pendulum Swings Again: Ocean Dumping Policy," *Environment*, vol. 24, June 1982, pp. 14-20.

[200] Kester, op. cit.

[201] J. P. Walsh, "U.S. Policy on Marine Pollution: Changes Ahead," *OCEANUS*, vol. 24, No. 1, 1981, pp. 18-24.

Uncontrolled Sites

This section discusses methods for the identification, evaluation, comparison, and remediation of uncontrolled sites. A number of policy issues associated with the CERCLA legislation and its implementation by EPA and the States are discussed in chapters 6 and 7. The objective of this section is to consider several **technical** areas related to cleaning up uncontrolled sites, including the problems of identifying sites, developing plans for cleanup, and selecting remediation technologies.*

The magnitude of the uncontrolled site problem is generally recognized to be substantial. Although the precise number has not been determined, there are probably some 15,000 uncontrolled sites in the Nation requiring remediation. Costs of remediation vary greatly but will probably average several million dollars per site.** The total national cost of cleaning up uncontrolled sites is probably in the range of $10 billion to $40 billion, far more than the current $1.6 billion estimated to be collected under CERCLA by 1985. A recent congressional analysis revealed that, through FY 1982, only $88 million of $452 million collected under CERCLA had been expended for cleanup, no cleanup funds had been earmarked or expended on 97 of the initial 160 priority sites determined by EPA, and only 3 CERCLA sites had been totally cleaned up (1 entirely with State funds).[202]

Uncontrolled sites fall into three categories:

1. Operational uncontrolled sites are those hazardous waste sites requiring, but not currently receiving, attention to ameliorate dangerous conditions. Either ongoing releases to the environment or the threat of imminent releases of hazardous waste would constitute such conditions.
2. Inactive sites are those sites no longer receiving hazardous waste and for which there is an identifiable responsible party or owner.
3. Abandoned sites are uncontrolled hazardous waste sites where no responsible party or owner has been identified, or where such parties lack the resources to take the steps needed to remedy danger conditions at the site.

Issues Concerning Effectiveness

The national effort to clean up uncontrolled sites is in its early stages. The magnitude of the problem, in terms of potential harm to human health and the environment and of potential costs of cleanup, is such that it is imperative to give considerable attention to three major issues, which are discussed below:

1. **What basis should be used to determine the end point for a remedial action? This is sometimes asked as the question "How clean is clean?"**

This question of extent of cleanup is often addressed by defining some nonharmful, or acceptable, level of contamination that may be left at a site after remedial actions are terminated. This approach, however, can be difficult to apply since the toxicological effects of many wastes and of low levels of some wastes are unknown. This could lead to somewhat arbitrary choices of acceptable residual chemical contamination.

Extent of cleanup can also be considered from the perspective of protection of the public and the environment in a cost-effective way. This may be accomplished by various approaches, such as:

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*For the purposes of this discussion, emergency response and "immediate" removal are not considered as remediation of a site. They are conventional actions associated with accidents and spills to remove immediate threats, generally followed by more technology-intensive and systematic efforts. Also, those activities defined within EPA's National Contingency Plan as "initial remedial" will not be considered as distinct, technologically, from remedial control technologies. Differences between these technologies concern timeframes, funding sources, and regulatory approaches rather than substantial technical differences.

**For example, the cleanup of one of the initial 160 priority sites, the Seymour site in Indiana, is estimated by EPA to cost $22.7 million to remove 60,000 barrels of wastes and to clean up contaminated soil and ground water beneath the site. An example of a less costly remedial action is the Trammel Crow site in Texas where five sludge pits with over 5 million gal of waste were cleaned up onsite using a solidification process and cost $378,000. In both cases additional moneys were spent for initial studies of the sites.

[202] Study by the House Subcommittee on Commerce, Transportation, and Tourism, as reported in Hazardous Waste Report, Nov. 1, 1982.

- An alternate water supply might be provided for a community using contaminated ground water, rather than cleaning the original supply. Such an approach might be appropriate for small numbers of water users, particularly when there might be a natural reduction of the contamination in time (e.g., with biodegradable organic waste). Sometimes outright purchases of the affected homes might be the most efficient way to accomplish the goal of limiting human exposure.
- Parties responsible for a number of sites might propose a partial cleanup, less than might be necessary to eliminate **all** potential future risk. Thus, buried drums and the most contaminated soil might be removed, without extensive ground-water recovery and treatment. Long-term environmental monitoring then would be provided to assure that there is no release in excess of predefined action levels.

2. **How can the relative cost-effectiveness of alternative cleanup approaches be determined?**

There are many difficulties in trying to analyze the economics and cost effectiveness of various remediation options. There is no question, however, that the costs of remediating uncontrolled waste sites are high. For example, the initial phases of site identification, evaluation, and assessment may cost from $50,000 to several hundred thousand dollars. The preliminary engineering efforts taken before remediation may cost several hundred thousand dollars more, and actual remediation generally costs from several hundred thousand dollars to several million dollars per site. There has not been enough accumulated experience to quantify and compare how effectively different technologies reduce risks. Some of the factors that affect analyses of cost effectiveness include:

- public policy regarding the level of acceptable risk subsequent to a site remediation remains unclear;
- the operating history of cleanup technologies at uncontrolled sites has not been sufficiently documented;
- the degree of success of the various technology options is sometimes site-specific. Therefore, the comparison of alternate technologies for a specific site remediation cannot always be extrapolated into a valid generic comparison;
- the long timespans involved in some of the technologies require assumptions regarding their long-term effectiveness. Some of the technology options generate future operation, maintenence, and monitoring costs that are difficult to estimate; and
- the possibility of systems failure and the need for subsequent remediation are difficult to predict. Only crude estimates of these potential "second-round costs" are available for comparison.

3. **Which current technologies may create future problems? Some technological choices could create needs for future remediation, for extended operation and maintenance procedures, with continuing risks and costs.**

The choice of a technology for site remediation can result in the need for certain long-term commitments. Such requirements might include physical maintenence of the grounds and site security if residuals of hazardous waste or other potential hazards remain after site remediation. Further, certain technologies, by virtue of the time needed for implementation (i.e., ground water recovery and treatment), involve long-term operation and maintenence costs. Also, there is a continuing level of risk during the implementation of these long-term technologies. These deferred costs, as well as the possible costs for alternate remedial technology if the initial control technology fails, should be considered when making a choice between an initially more expensive remediation (e.g., excavation with offsite disposal or treatment) and a long-term technology with lower initial cost (e.g., encapsulation).

Taking remedial actions that are effective in the long term is advisable because new uncontrolled sites are likely to be identified, requiring still further expenditures in the future. Current practices of land disposal of hazardous waste may be creating future needs for remedial action. Disposal sites, even state-of-the-art installations meeting regulatory standards for design, operation, closure, and post-closure monitoring, do not always eliminate the possibility of releases of hazardous materials into the environment. Moreover, because of a number of exemptions in RCRA itself and of those resulting from administrative decisions, hazardous wastes are being disposed in subtitle D sanitary landfills that are not designed for hazardous waste. Such facilities have already accounted for large numbers of uncontrolled sites, and others will likely become uncontrolled sites.

Site Identification and Evaluation

The amount of information available regarding uncontrolled sites (e.g., location, number, and level of hazard) is generally recognized to be incomplete. There are continuing efforts at both the Federal and State levels to identify uncontrolled sites, with the problem being acute for abandoned sites for which there are no responsible parties available to provide detailed information (see ch. 7). It is generally accepted that many thousands of uncontrolled sites exist.

There are three means of identifying uncontrolled sites:

1. Federal and State efforts to prepare inventories of sites based on file information or on field investigations;
2. reporting by the general public and by parties such as developers that may discover sites accidentally; and
3. requirements that industries producing or managing hazardous wastes submit information on sites either created by them or known to them.

Following the identification of a problem site, considerable data is required for evaluation of the level of hazard posed by the site. Relevant data include both physical and descriptive factors. Physical considerations include the population or environment at risk; critical pathways; site conditions, including hydrogeologic characteristics; waste amounts, forms, and compositions; and evidence of actual releases. Table 37 summarizes the types of data required. Nontechnical descriptive information might be collected concerning history of the site, ownership, adjacent properties, previous administrative or legal actions, associated potentially responsible parties such as generators and waste haulers, and other relevant background information. These nontechnical types of information are important for obtaining more detailed technical information, as

Table 37.—Data Required To Identify and Evaluate Uncontrolled Sites

Type of data—specific factors
Site assessment:
Wastes:
• Quantity
• Composition
• Form
• Condition of waste (containerized, bulk, buried, open lagoon)
• Acute hazards (acute toxicity, flammability, explosiveness, etc.)
• Chronic cumulative hazard (toxicity, mutagenicity, carcinogenicity, teratogenicity, radioactivity, etc.)
• Synergistic/antagonistic components
Site:
• Geological features
• Topographical features
• Vegetation
• Surface water
• Ground water
• Structures
• Access
Exposure:
Releases:
• Past or present releases
• Potential for future releases
• Migration routes of releases (air, ground water, surface water, overland flow or runoff, etc.)
Potential exposure:
• Estimates of release quantities
• Exposure routes
Risk:
Environments:
• Waters
• Land areas
• Air
• Vegetation
• Wildlife
• Agricultural areas
• Recreational areas
Populations:
• Location
• Sensitivity
• Numbers

SOURCE: Office of Technology Assessment.

well as for other purposes, such as enforcement actions. This is necessary because site inspections are difficult, costly, and sometimes dangerous, and because there often is no immediate source of technical information.

A site inspection to observe surface conditions may include:

- sampling of wastes, and surface and ground waters,
- air monitoring,
- some random excavation to identify buried materials,
- magnetic surveys to locate buried metal (possible containerized material),
- resistivity surveys (to determine whether there is underground contamination), and
- an assessment of site conditions in general.

Determining what a site contains can present substantial problems of sampling and analysis. Only a limited number of samples can be taken because sampling itself can pose risks of release of hazardous materials from the site. With hundreds or thousands of drums that are often unmarked, and a relatively small number of samples taken, there is no assurance that analysis will accurately indicate the hazardous contents of the site, or that any hazardous materials will be discovered. There are also substantial problems concerning the detection of hazardous materials in underground water supplies. There is no consensus on drilling methods, sampling frequency or protocol, standard quality assurance procedures, or the number of wells needed to define problems. Drillers run the risk of contaminating clean aquifers while drilling into polluted ones.

There are also considerable problems concerning chemical analysis. Standard methods such as mass spectroscopy do not necessarily yield useful results for many chemicals. Newer, sophisticated laboratory procedures may require laboratory facilities not available to investigators. There are few standard testing procedures for complex waste constituents. Waste may contain byproduct chemicals, or altered chemicals, and laboratories may not have standards for their identification. **There are indications of substantial problems concerning quality control in both government and private laboratories.**

Techniques for the comparison of sites often involve the combination of various "weighted" components of hazard into a single numerical measure for a site. Such values for various sites are compared in order to produce a ranked listing, from which remedial priorities are then established. (see chs. 6 and 7 for discussions of hazard evaluations, risk assessment, and ranking systems).

Site Cleanup Plans

Once a decision is made to proceed with remedial action at a site, it becomes necessary to establish a step-by-step procedure for implementation. The basic steps in remedial action or site cleanup are:

1. preliminary assessment,
2. feasibility study,
3. engineering design,
4. construction,
5. startup, trouble shooting, and cleanup, and
6. possible long-term operation and maintenance.

Following assessment and the decision to effect remediation, the feasibility study would identify alternative engineering options for mitigation, including limitations, costs, and effectiveness. The feasibility study should evaluate the various remedial technologies for the specific conditions at the site under consideration. The basic technological options are:

1. removal followed by appropriate disposal or treatment—e.g., fixation, neutralization, or any other conventional technology, or by treatment of the waste on the uncontrolled site (see discussion earlier in this chapter);
2. pathway control through encapsulation or containment, or by ground or surface water diversion;
3. mitigation of exposures by providing an alternate water supply, land use restrictions, or evacuation of people;

An important issue concerning the choice of remedial technologies, because of current EPA policies (see ch. 7), is the difference in initial, capital costs v. longer term operating and maintenance (O&M) costs. The specifics of O&M depend on the technology chosen. Those technological options that permanently deal with the hazard often have high initial costs and low O&M costs. Conversely, those options that, for example, do not destroy or treat the waste to reduce risks are likely to have high and uncertain O&M costs. For example, excavation and removal followed by treatment or disposal would initially be both capital-intensive and labor-intensive, but subsequent O&M requirements would be minimal. Alternatively, encapsulation with ground water recovery and treatment would generally incur lower initial costs but have subsequent large O&M costs.

Implementation of engineered remedial activities at a site may require a wide variety of ancilliary and support activities, depending on the conditions at the specific site and the choice of control technology. Epidemiological studies may be required when there has been a release of hazardous waste that may have affected public health or if there is a need for baseline data to monitor future effects arising from the choice of site-control technology. Chemical analysis may also be needed for many purposes, ranging from quality control work during cleanup, protection of onsite workers exposed to hazardous materials, to verification that the intended level of cleanup has been reached.

Technical Approaches for Remedial Control

The following review and discussion of the generic technology options is based on consultations with professionals working in the area of uncontrolled site remediation, a recent study for EPA of remediation technologies,[203] and proceedings from annual conferences on uncontrolled hazardous waste sites.[204] Any technological option for site remediation has limitations that will keep it from being effective under **all** circumstances. Examples of technologies are discussed below, and a summary of the advantages and disadvantages of primary technological options is given in table 38. A recent survey of technologies used at uncontrolled hazardous waste sites indicates the distribution of currently used technologies, as shown in table 39. These technologies may be grouped into two broad categories:

- waste control technologies; and
- environmental pathway control.

Waste control technologies for uncontrolled sites act on the amount of waste or on some hazardous property or constituent of the waste. Such methods include:

- **Excavation and removal offsite of the hazardous waste.**—This method is suitable for all sites with containerized or bulk disposal of waste. Normally it must be followed with some type of secondary cleanup of ground water if the materials deposited were water soluble, and evidence shows ground water contamination. While such techniques eliminate or minimize both future O&M costs and future risk to the public and environment, there are high initial costs, with possible higher risk of exposure during the period of excavation. To some degree, risk may be relocated depending on the offsite disposal option chosen. Populations and environments along routes chosen for transportation between sites and disposal facilities are exposed to risk of spills while wastes are in transit. Those responsible for the remedial action become generators under the provisions of RCRA with all the associated responsibilities and liabilities. Such methods are neither cost effective for large amounts of low-level hazardous waste, nor for uncontainerized buried waste dispersed through a large area.
- **Excavation with onsite treatment.**—This approach can be used for some onsite treatment technologies such as fixation, use of **mobile treatment units** for physical or chemical treatment or incineration, or for site preparation and lining prior to reinterment. Such methods can expose wastes quite efficiently to a treatment

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[203] Environmental Protection Agency, "Handbook—Remedial Action at Waste Disposal Sites," EPA 625/6-82-006, June 1982.

[204] These volumes are published by the Hazardous Materials Control Research Institute, Silver Spring, Md.

Table 38.—Advantages and Disadvantages of Control Technologies

Type	Advantages	Disadvantages
Waste control technologies:		
Excavation and removal followed by treatment or disposal	a) Good for containerized or bulk disposal	a) High initial costs b) Potential higher risk during cleanup c) Relocation of risk unless waste is treated d) Not cost effective for low-level hazardous waste or uncontainerized buried waste in large area
Excavation with onsite treatment option	a) Expose waste to complete treatment b) No offsite exposure	a) High initial cost b) Difficult to assure monitoring effectiveness c) Some risk of exposure d) Not cost effective for large amount of low-hazard waste
Neutralization/stabilization	a) Useful in areas where waste can be excavated prior to mixing b) Low risk of exposure if injection method is used	a) Limited application b) Requires long-tenn land use regulations c) Eventual offsite migration if reaction is incomplete
Biodegradation	Low costs	Difficult to maintain optimum conditions to keep reaction going
Solution mining	Useful in homogeneous uncontainerized solvent-soluble, buried solid hazardous waste	Can result in uncontrolled release
Environmental pathway (vector) control:		
Isolation, containment, and encapsulation	Useful for large volumes of mixed hazardous and domestic waste, and low-hazard waste	a) Effectiveness depends on physical conditions at site b) Long-term O&M needed
Ground water diversion and recovery	Useful if soils are permeable or if there are high or perched water tables	a) Requires wastewater treatment option b) Process is slow c) O&M monitoring d) Not effective for insoluble or contain erized material
Surface water diversion	a) Easy to implement b) No transport of waste offsite	Can create flooding offsite
Ground and surface water treatment	a) Can be used onsite or offsite	a) May generate hazardous sludges, spent carbon b) Long-term monitoring
Gas collection or venting	Low costs	a) Site safety and fire hazards b) Offsite air pollution c) Long-term monitoring and O&M

O&M—operating and maintenance.

SOURCE: Office of Technology Assessment.

process and, in some cases, may be less expensive than excavation followed by transportation to an offsite treatment facility. Offsite populations are not exposed to possible spills. Future O&M costs are eliminated with future risks if waste destruction or detoxification options are also implemented. There is a high initial cost, and long-term monitoring is required when the reinterment option is chosen. Local population is subject to additional risks inherent in the excavation and exposure of buried waste, as well as those inherent in the mobile treatment process chosen. This technology is not cost effective for large amounts of low-level waste and is not effective for uncontainerized waste dispersed through a large area.

- **Direct neutralization/stabilization/fixation.**—This technology is used primarily for large volumes of homogeneous uncontainerized liquids or sludges. Agents are injected directly into the ground where wastes are buried. Neutralization, an acid-base balancing mechanism, aids in the removal of hazardous constituents through

Table 39.—Types of Remedial Action Employed at a Sample of Uncontrolled Sites

Remedial action	Number of sites[a]	Percent of total
Waste actions:		
Drum and contaminant removal	126	41%
Contaminant treatment	48	16
Incineration	3	1
Dredging	5	2
Action on route of release:		
Capping/grading	59	19
Ground water pumping	22	7
Ground water containment	23	8
Encapsulation	8	3
Gas control	3	1
Lining	7	2
	304	100%

[a] As many as 25 spill sites may be included.

SOURCE: S. R. Cochran, et al., "Survey and Case Study Investigation of Remedial Actions at Uncontrolled Hazardous Waste Sites," in *Management of Uncontrolled Hazardous Waste Sites*, Hazardous Materials Control Research Institute, 1982, pp. 131-135.

precipitation. Fixation immobilizes soluble waste by binding them with a stable material. Thus, an immobile solid is formed. Onsite applications eliminate the need for offsite disposal areas or for site upgrading following removal of excavated materials. There is low risk of exposure to buried waste when the injection option is chosen. However, the technology has limited application and requires long-term land use restrictions at the site along with environmental monitoring. Reaction or immobilization may be incomplete, and there may be eventual breakdown and stripping from repeated flushing by ground water, resulting in subsequent offsite migration of hazardous waste.

In addition, other detoxification techniques to be used at the site are being researched. One method is a chemical dechlorination or dehalogenation process which uses a sodium or potassium polyethylene glycol reagent. The sodium reagent (NaPEG) patented by the Franklin Research Institute. EPA has been working with the Institute to find a faster acting reagent using potassium. In the envisioned practice, the reagent would be spread over a spill or dump site. Perhaps it would be covered for rain protection and to raise temperature, and perhaps reapplied in several days. In principle, a series of reactions takes place, replacing at least some of the chlorine atoms with the reagent glycols theoretically forming less toxic and less bioaccumulative compounds. In unpublished EPA testing, a solution of 1,000 ppm hexachlorobenzene was destroyed with 95 percent efficiency in 7 days at room temperature, and reapplication achieved completion.[205] However, the chemistry of this process at ambient temperatures and in the presence of water has yet to be proven, and little has been published. Important questions concerning the composition of the resulting compounds and their toxicities remain to be studied. Further, these reagents have not yet been applied outside the laboratory.

- **Biodegradation.**—Microbial degradation techniques have been applied to uncontainerized, biodegradable organic waste, usually for spills. It possibly might be used as a final step to remove low concentration residuals left at sites after the use of other technologies, such as excavation with offsite disposal or ground water recovery and treatment. Biodegradation is usually a low-cost option. However, the method requires acclimated organisms, and supplemental injections of nutrients or oxygen may be required to support biological action. The limited applications are slow and are affected by ambient temperature.
- **Solution mining.**—This method is restricted to limited (and unusual) situations where a homogeneous, uncontainerized, solvent-soluble, solid hazardous waste is buried. Solvent is injected into the site and recovered through a series of well points. Various applications of this technology use water as the solvent. Caution must be taken that dissolving nonmobile hazardous waste does not produce an uncontrolled release or leave behind dissolved and mobile material.

Environmental pathway control for hazardous waste sites attempt to inhibit offsite migration of hazardous materials by a number of methods, as discussed below. The most common route amenable to such controls is water—surface, ground, and rainwater; although gas controls are sometimes used at sites where methane or other gases are present. In most cases, there is a continuing need for monitoring and potential need for repeated remedial actions. Pathway control technologies include:

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[205] Charles Rogers, Environmental Protection Agency, Office of Research and Development, IERL, personal communication, January 1983.

- **Isolation, containment, and encapsulation techniques.**—Mechanical barriers—e.g., in capping, bottom sealing, and perimeter containment barriers—use natural materials (e.g., clay) or synthetic impermeable materials (e.g., asphalt, cement, polymer sheet, chemical grout) that are either poured, injected, or placed into desired locations to provide containment or inhibit water intrusion on buried hazardous waste. Surface contour modifications and revegetation are used to enhance rainwater runoff or to capture it for subsequent removal via natural processes of evaporation and transporation. Such methods are used in those situations where no onsite treatment or removal is planned or where there is a need to contain residuals from such actions. They are most practical at sites with extremely large volumes of mixed hazardous and domestic wastes or with widespread low-level contamination (e.g., mine tailings or contaminated soil) where costs of alternative actions are prohibitive. The costs of these techniques are favorable compared with those of other options, and exposure of buried waste is not required. The effectiveness of these methods, however, is greatly dependent on ambient environmental conditions, such as geohydrology, precipitation, and geomorphology. Long-term O&M as well as long-term monitoring are required.[306] Failure may require additional remedial action. Security for this approach, where the water route is of concern, can be enhanced by combination with a ground water recovery and treatment system.
- **Ground water diversion and recovery.**—These methods make use of collection and diversion trenches or of well points with pumping, and sometimes in combination with subsequent up-gradient injection or percolation ponds to shift piezometric surfaces. The technology is useful in situations where underlying soils are permeable (e.g., sands or fractured shales where well points may be used) or at sites with a high or perched water table and underlying clay or other tight formations where trenches may be used. These diversion methods are effective for collecting highly contaminated leachate before dilution after mixing with main body of ground water. Effective recovery can be enhanced with up-gradient injection. Ground water flow rates consequently are increased, and an augmented volume of flush water is provided to wash soluble hazardous constituents from the site to the collection system. This technology generally requires waste water treatment, although collected water can be directly discharged to a surface stream if it meets applicable discharge standards. The process is slow and requires O&M and constant monitoring of the collection system and the offsite environment. It is not effective for containerized materials or insoluble waste.
- **Surface water diversion.**—These diversion methods are used where surface streams run through or near an uncontrolled site. Such systems are relatively easy to implement with existing technology. Addition of undesirable water on the site is not required, and associated offsite transportation of hazardous materials is reduced. However, offsite flooding problems may be created.
- **Ground and surface water treatment.**—These treatment methods may be used where there is a system to recover contaminated water and may be implemented either offsite or onsite. Treatment technol-

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[306] A recent study on the use of slurry wall installations concluded: "Unfortunately, most of the slurry wall installations to date have been in the private sector, from which little monitoring data are available. Until such data are assembled and critiqued, it remains to be seen just how effective, and how long term this remedial measure is in controlling the spread of contaminated ground water." P. A. Spooner, et al., "Pollution Migration Cut-Off Using Slurry Trench Construction," in *Management of Uncontrolled Hazardous Waste Sites*, Hazardous Materials Control Research Institute, 1982, pp. 191-197.

ogy is the same as for other aqueous wastes—biological, carbon absorption, physical/chemical, or air stripping. Various levels of treatment can be chosen in combination with appropriate collection methods. Effectiveness is limited by the ability of the associated collection system to contain and recover the hazardous waste. There have been some operational problems where waste characteristics vary, as is often encountered at hazardous waste sites that have a history of receiving mixed waste, although batching and equalization can minimize this problem. Hazardous waste in the form of sludges and spent carbon may be generated.

- **Gas collection or venting.**—These methods are used for collection of gases for treatment, or for controlled venting of gases generated at a site from decomposition of organic matter or from chemical reactions of waste. Such technologies provide methods of handling toxic or flammable gases that may present site safety and fire hazards as well as offsite air pollution threats. Long-term monitoring is required, and there are O&M costs.

Appendix 5A.—Case Examples of Process Modifications

Chlor-Alkali Process

The production of chlorine and sodium hydroxide is an important process in the chemical industry. These chemicals are major materials for the manufacture of many different consumer and industrial products such as pulp and paper, fibers, plastics, petrochemicals, fertilizers, and solvents. The production process is a large-scale system in which modifications have been extensively implemented in the past to achieve higher process efficiencies. Significant reduction of hazardous waste generation is possible through still further process modifications.

The chlor-alkali process is based on electrolysis of brines—i.e., an electric current is passed through a solution of sodium chloride to produce chlorine, hydrogen, and sodium hydroxide. Two basic process designs were originally developed: one incorporates a mercury cell and the other utilizes a diaphragm cell. Each type of cell has advantages and disadvantages which will be discussed below.

Mercury Cell Process.—This process yields a very high quality of sodium hydroxide. A disadvantage, however, is that it results in a large concentration of mercury discarded in process waste. Although this process accounts for only 25 percent of the chlorine production in the United States, approximately 42,000 tonnes of mercury-contaminated brine are disposed in landfills on an annual basis. Source segregation technologies do exist to remove some of the mercury from waste, but complete removal is not possible. Waste containing various chlorinated hydrocarbons also are produced.

Diaphragm Cell Process.—The advantage of this process is that it does not use mercury. If a graphite electrical terminal is used, the waste contains chlorinated hydrocarbons that are considered hazardous constituents (e.g., chloroform, carbon tetrachloride, and trichloroethane). Another source of hazardous waste using this process is the asbestos diaphragm. While not yet regulated under RCRA, disposal of asbestos is limited by regulations promulgated for the Toxic Substances Control Act.

Three modifications have occurred that reduce the amount of hazardous waste generated in a chlor-alkali process. The first has been substitution of a diaphragm cell for the mercury cell in most production facilities in the United States. This has been possible because of the availability of natural salt brine in this country, which is a preferred raw material for the diaphragm cell process. This substitution has been quite successful; in the last 15 years, no new mercury cell plants have been constructed.

A second modification has reduced successfully the amount of chlorinated hydrocarbons found in process waste. This was accomplished by replacing the graphite anode with a dimensionally stable anode (i.e., an electrical terminal). In addition to the reduction of hazardous constituents in waste, this modification contributed to a more efficient and longer cell life.

The third modification, development of a membrane cell, incorporates a major change in the type of membrane used in the diaphragm cell process. The asbestos membrane is replaced with an ion-exchange membrane, which generates a higher quality of sodium hydroxide. This quality is similar to that produced by the mercury cell. Full development and use of this modification would reduce the amount of hazardous waste generated in two ways:

1. mercury contamination in chlor-alkali waste would be eliminated by a complete phase-out of the mercury cell process, and
2. the amount of asbestos waste would be reduced.

The membrane cell is a new modification and has not yet been incorporated on a large scale. A total of 25 units of various sizes have been built in the world. A small unit (11 tonnes/day) currently is operating in a U.S. pulp mill. A larger unit (220 tonnes/day) will be in operation in the United States by late 1983. The capital investment required for incorporation of a membrane cell is slightly higher than a diaphragm cell that also offers a savings in energy costs. For those facilities with capacities of less than 500 tonnes/day, a membrane cell is more economical than a diaphragm cell. At greater capacities, neither system is superior, and other factors will determine the selection. These include the availability of appropriate raw material (e.g., natural salt brine or solid forms of sodium chloride) and ease of retrofitting an existing facility.

Vinyl Chloride Process

Vinyl chloride monomer (VCM) is one of many chemicals manufactured by the chlorohydrocarbon industry. This chemical is considered a hazard to human health, its production is regulated under the Occupational Safety and Health Act, and its disposal is regulated under RCRA. It is an intermediate product in the manufacture of PVC and can be produced by several different manufacturing routes.

About 92 percent of all VCM plants in the United States have both oxychlorination and direct chlorination plants onsite. The manufacture of VCM produces gaseous emissions of the monomer and liquid process residues that are a mixture of chlorinated hydrocarbons.

Incineration of these process wastes is used to recover hydrogen chloride, which is either recycled back to the VCM process or neutralized. Conventional incinerators designed for onsite treatment of many different wastes are not effective in the treatment of chlorinated hydrocarbons, as incomplete combustion results. Therefore, high-efficiency incineration specifically designed for liquid or gaseous chlorinated hydrocarbons is used. Although success with incineration systems has been mixed, reliable performance has been demonstrated with relatively few operating problems.

Chlorinolysis represents a recovery option. High pressure and temperatures are used to reduce the liquid chlorohydrocarbon waste to carbon tetrachloride. This system has two major drawbacks: 1) the capital costs are high because of the high pressures and temperatures; and 2) the demand for carbon tetrachloride is decreasing due to regulatory restrictions on the use of products for which it is a raw material—e.g., fluorocarbons. Therefore, chlorinolysis is an unlikely choice in the future reduction of liquid waste from VCM production unless new uses are found for carbon tetrachloride.

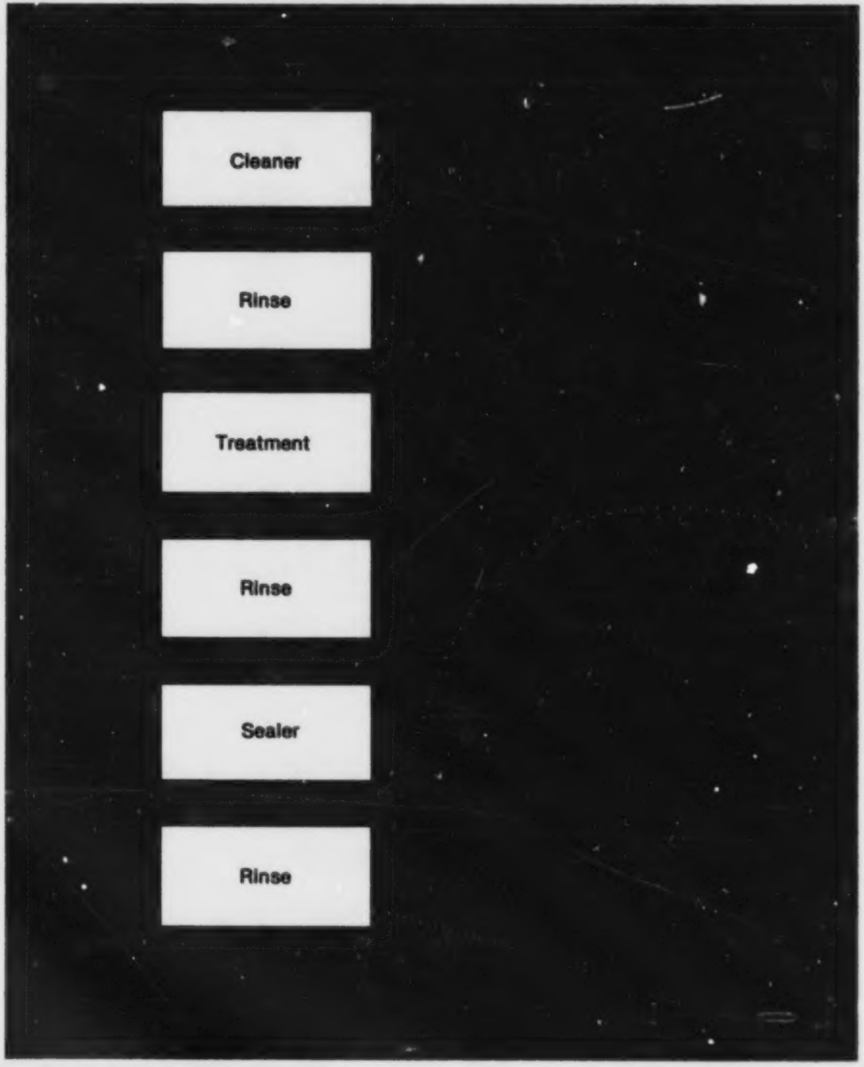
Another option for handling VCM liquid waste is to use a catalytic fluidized-bed reactor process developed by B. F. Goodrich. Hydrogen chloride gas is recovered and can be recycled without further treatment as feedstock in the oxychlorination process. The advantages of this system are low temperature operation, direct recycling of hydrogen chloride without additional treatment requirements, and energy recovery. The primary disadvantage of this recovery process results from restrictive requirements for application—i.e., only a plant using an oxychlorination process in conjunction with a fixed-bed reactor can accept the hydrogen chloride gas as feedstock. If an oxychlorination plant has a fluidized-bed reactor, the hydrogen chloride must be adsorbed from the gas stream and recovered with conventional recovery technology. The added cost of the absorption process makes this option prohibitive for fluidized-bed oxychlorination plants.

Metal-Finishing Process

Several modifications in metal cleaning and sealing processes have enabled the metal-finishing industry to eliminate requirements for corporation owned and operated wastewater pretreatment facilities. An example is provided in figure 5A.1. This process is designed to remove oil and grease from metal parts and seal the surface in preparation for application of a coating. The process consists of six stages. The parts are cleaned in stage I, rinsed in stage II, treated in stage III, rinsed in stage IV, sealed in stage V, and rinsed in stage VI.

The first modification is the incorporation of flow controllers to decrease the volume of water used in rinse. This results in a reduced volume of potentially hazardous sludge. While the flow in rinse stages IV and VI can be controlled without affecting other stages, any change in stage II will affect

Figure 5A.1.—Metal Preparation for Coating Applications



SOURCE: Office of Technology Assessment.

directly the quantity of chemicals required for stage III. For example, a decrease in rinsewater flow produces a more alkaline rinse. Thus, more acid is required in stage III. Increased acid levels also require additional amounts of metallic ions, such as nickel and zinc. Therefore, any changes in flow control for stage II must be carefully balanced with increased chemical requirements for stage III.

A second process modification occurs in stage III with the replacement of nickel and zinc by less hazardous metals. Zinc can be substituted for nickel and, for certain applications, manganese or iron can be substituted for zinc. Presence of iron in wastewater actually can be beneficial for municipal waste treatment processes as it facilitates removal of phosphorus.

An acidic solution containing chromium in both the hexavalent and trivalent states is normally used in stage V. A third modification involves replacement of hexavalent with the trivalent chromium, reducing the hazard. The chromium can be replaced entirely with a biodegradable organic compound. These modifications made in stages III and V permit discharge of metal-finishing wastewater directly into municipally owned treatment facilities. Such changes also eliminate formation of hazardous sludge.

Case Examples of a Recovery/Recycle Operation

Recycling of Spent Pickle Liquor in the Steel Industry

A major waste disposal problem for the steel industry concerns spent liquor from a pickling operation. The pickling process removes surface scale and rust from iron and steel prior to application of a final coating. The metal is immersed in an acid bath and as the scale dissolves, iron salts are formed. The contaminated acid bath is known as spent pickle liquor.

Approximately 500 million gal/yr of spent pickle liquor are generated from acid pickling. This solution contains 0.5 to 16 percent acid and 10 to 25 percent ferrous salts. Ninety percent of the total acid is hydrochloric or sulfuric acid; the remainder often includes nitric acid. The presence of nitric acid in spent liquor will determine which recovery option is possible.

Several disposal/treatment options are available:

- injection into deep wells;
- neutralization of the spent pickle liquor (using lime, soda ash, or caustic soda to increase the pH level) and landfilling the resulting sludge;
- recovery and regeneration of acid;
- byproduct recovery; and
- discharge to wastewater treatment facilities.

Because increased transportation costs and stricter regulations have limited the availability of suitable deep wells, costs for containing spent liquor have risen steadily. The gelatinous iron hydroxide sludge formed after neutralization creates a disposal problem, and costs of chemicals required for neutralization also have increased. Thus, the attractiveness of the first two options is reduced.

The remaining options involving some type of recycling and/or recovery have become more viable. Spent liquor can be used directly in treatment of municipal wastewater for removal of phosphorus. Addition of spent sulfuric acid has been shown to be particularly effective for water and wastewater treatment. Acid recovered from spent liquor can be recycled back to the pickling process. The salts formed (ferrous sulfate from sulfuric acid pickling and ferrous chloride from hydrochloric acid pickling) have several uses. For example, ferrous sulfate crystals currently are used in the manufacture of pigments, magnetic tapes, fertilizers, and in wastewater treatment. Potential markets for recovered ferric oxide salts are in magnetic tapes, pigments, steelmaking, and sintering operations.

Sulfuric and hydrochloric acid pickling account for 85 to 90 percent of all pickling operations in the United States. Presumably, recovery of these acids for recycling could reduce spent liquor disposal by that same percentage. Because spent pickle liquor represents a large-volume hazardous waste, recovery and recycle could reduce the volume of hazardous waste disposed.

Recovery Technologies

Recovery processes are designed to recover either the free acid or both free acid and iron salts. Two methods are available for recovery of spent sulfuric and hydrochloric acid liquor. Cooling of the liquor results in separation of ferrous sulfate crystals. The unit operations required in this recovery system are: 1) precooling, 2) crystallization, 3) slurry thickening, and 4) crystal separation by centrifugation. Another process involves roasting the ferrous sulfate to produce ferric oxide and sulfur dioxide. The sulfur dioxide can be scrubbed to regenerate sulfuric acid. This is similar to the roasting process originally developed for recovery of hydrogen chloride.

Spent liquor from hydrochloric acid-pickling operations recovery technology is similar to the above sulfuric acid recovery technologies. Roasting ferrous chloride produces ferric oxide and hydrogen chloride gas. Auxiliary fuel is used to maintain reactor temperature at 1,500° F. The hydrogen chloride gas generated is absorbed in water to form hydrochloric acid for recycle. Unit operations include: 1) evaporation, 2) high-temperature decomposition, 3) absorption, and 4) scrubbing of vent gases.

Economic Factors.—The economics of acid recovery are based on cost and availability of acid, disposal cost of spent pickle liquor, quality and market value of byproducts (iron sulfate or iron oxide), and cost of selected recovery processes. Each of these factors is dependent on the particular plant and process involved.

Major economic advantages of acid recovery are reduced raw material costs, elimination of transportation costs incurred in disposal of spent liquor or sludge, and byproduct sales credits. The major economic disadvantages are utility requirements (primarily fuel requirements for hydrogen chloride recovery from dilute aqueous solutions) and capital investment requirements.

Byproduct recovery of spent liquor for wastewater treatment does not require a capital investment. This is a major advantage for this option. However, disposal costs and repurchase of acid have been estimated at $110/tonne compared to recovery costs of about $22 to $88/tonne.

Corporate Factors.—Regional recovery/recycle facilities provide the opportunity of transferring burdens of investment cost from individual steel operations to a commercial recovery developer and offer reduced risk. However, regional facilities imply increased storage requirements. Storage of spent liquor can create certain problems, e.g., premature precipitation of ferrous sulfate during periods of low temperature. In addition, early separation of acid from various sources of spent liquor may be required to eliminate potential contamination from proprietary chemical additives. Another disadvantage to a regional facility is added costs for transportation of spent liquor and recovered acid from the generator to the recovery facility and then to the consumer.

Table 5A.1.—Summary Evaluation of Liner Types

Liner material	Characteristics	Range of costs[a]	Advantages	Disadvantages
Soils:				
Compacted clay soils	Compacted mixture of onsite soils to a permeability of 10^{-7}cm/sec	L	High cation exchange capacity; resistant to many types of leachate	Organic or inorganic acids or bases may solubilize portions of clay structure
Soil-bentonite	Compacted mixture of onsite soil, water and bentonite	L	High cation exchange capacity; resistant to many types of leachate	Organic or inorganic acids or bases may solubilize portions of clay structure
Admixes:				
Asphalt-concrete	Mixtures of asphalt cement and high quality mineral aggregate	M	Resistant to water and effects of weather extremes; stable on side slopes; resistant to acids, bases, and inorganic salts	Not resistant to organic solvents; partially or wholly soluble in hydrocarbons; does not have good resistance to inorganic chemicals; high gas permeability
Asphalt-membrane	Core layer of blown asphalt blended with mineral fillers and reinforcing fibers	M	Flexible enough to conform to irregularities in subgrade; resistant to acids, bases, and inorganic salts	Ages rapidly in hot climates; not resistant to organic solvents, particularly hydrocarbons
Soil asphalt	Compacted mixture of asphalt, water, and selected in-place soils	L	Resistant to acids, bases, and salts	Not resistant to organic solvents, particularly hydrocarbons
Soil cement	Compacted mixture of Portland cement, water, and selected in-place soils	L	Good weathering in wet-dry/freeze-thaw cycles; can resist moderate amount of alkali, organics and inorganic salts	Degraded by highly acidic environments
Polymeric membranes:				
Butyl rubber	Copolymer of isobutylene with small amounts of isoprene	M	Low gas and water vapor permeability; thermal stability; only slightly affected by oxygenated solvents and other polar liquids	Highly swollen by hydrocarbon solvents and petroleum oils; difficult to seam and repair
Chlorinated polyethylene	Produced by chemical reaction between chlorine and high density polyethylene	M	Good tensile strength and elongation strength; resistant to many inorganics	Will swell in presence of aromatic hydrocarbons and oils
Chlorosulfonate polyethylene	Family of polmers prepared by reacting polyethylene with chlorine and sulfur dioxide	H	Good resistance to ozone, heat, acids, and alkalis	Tends to harden on aging; low tensile strength; tendency to shrink from exposure to sunlight; poor resistance to oil
Elasticized polyolefins	Blend of rubbery and crystalline polyolefins	L	Low density; highly resistant to weathering, alkalis, and acids	Difficulties with low temperatures and oils
Epichlorohydrin rubbers	Saturated high molecular weight, aliphatic polethers with chloromethyl side chains	M	Good tensile and tear strength; thermal stability; low rate of gas and vapor permeability; resistant to ozone and weathering; resistant to hydrocarbons, solvents, fuels, and oils	None reported
Ethylene propylene rubber	Family of terpolymers of ethylene, propylene, and nonconjugated hydrocarbon	M	Resistant to dilute concentrations of acids, alkalis, silicates, phosphates and brine; tolerates extreme temperatures; flexible at low temperatures; excellent resistance to weather and ultraviolet exposure	Not recommended for petroleum solvents or halogenated solvents
Neoprene	Synthetic rubber based on chloroprene	H	Resistant to oils, weathering, ozone and ultraviolet radiation; resistant to puncture, abrasion, and mechanical damage	None reported
Polyethylene	Thermoplastic polymer based on ethylene	L	Superior resistance to oils, solvents, and permeation by water vapor and gases	Not recommended for exposure to weathering and ultraviolet light conditions
Polyvinyl chloride	Produced in roll form in various widths and thicknesses; polymerization of vinyl chloride monomer	L	Good resistance to inorganics; good tensile, elongation, puncture, and abrasion resistant properties; wide ranges of physical properties	Attacked by many organics, including hydrocarbons, solvents and oils; not recommended for exposure to weathering and ultraviolet light conditions
Thermoplastic elastomers	Relatively new class of polymeric materials ranging from highly polar to nonpolar	M	Excellent oil, fuel, and water resistance with high tensile strength and excellent resistance to weathering and ozone	None reported

[a] L = $1 to $4 installed costs per sq. yd. in 1981 dollars; M = $4 to $8 per sq. yd.; H = $8 to $12 per sq. yd.

SOURCE: "Comparative Evaluation of Incinerators and Landfills," prepared for the Chemical manufacturers association, by Engineering Science, McLean, Va., May 1982.

CHAPTER 6

Managing the Risks of Hazardous Waste

Summary Findings

1. Methodologies for risk assessment are not perfectly developed. If data are analyzed with care and uncertainties recognized, currently available tools can be used effectively in risk-management decisions. Continued research and development are needed to improve the methodologies.

2. Classification systems can be developed to group wastes by degree of hazard and management facilities by degree of risk. Although technical problems must be solved, classes of waste and management facilities can be matched to minimize risks to human health and the environment.

3. Advantages of a classification system include:
   - wastes would be assigned to appropriate levels of management to achieve a consistent level of protection without unnecessary expense;
   - government officials could set priorities for establishing standards and controls based on objective criteria; and
   - the system could provide the public with reliable information on the relative hazards of different classes of waste and the most appropriate ways of handling each to reduce risks.

4. Among the problems that must be solved in designing an effective classification system are:
   - criteria for classifying waste must be carefully selected to include the broad range of threats to public health and the environment (e.g., to include long-range effects such as reproductive impairment as well as short-range ones such as acute toxicity);
   - the combined, or synergistic, effects of waste constituents must be considered, not just the effects of single constituents alone;
   - the hazard of a waste may be changed by a management technology, thus the constituents that are released from a facility may be more (or less) hazardous than the original waste. Risks to public health are determined by the hazard of constituents leaving a facility (i.e., releases);
   - characteristics used to classify waste are not always the same as those that determine the appropriate management technology; therefore a mismatch of waste and facilities could occur; and
   - boundaries of waste and facility classes would have to be clearly defined, to achieve consensus among regulators, the industry, and the public.

5. Monitoring is a key component in regulation of hazardous waste. It is the only way to verify that a waste management system is operating correctly. Data on the chemical, structural, and physical characteristics of waste constituents can be used to predict their environmental fate. Knowledge about fate of constituents can be used to develop cost-effective programs.

6. Of five types of monitoring activities—visual, source, process, ambient, and effects—ambient monitoring provides the best evidence for judging whether risks of hazardous waste management are being kept at acceptable levels. If environmental contamination is prevented, human exposure will be reduced and public health protected. Therefore, ambient monitoring should receive greater attention in regulatory programs.

7. All monitoring has problems associated with sampling, data comparability, and limitations of methodology. Possible actions to correct the deficiencies include:

- a central monitoring activity, drawing on government and nongovernment resources;
- a nationally supported pilot project to develop a monitoring framework, including standard procedures for sampling, data storage, and analysis; and
- a coordination of monitoring efforts mandated in the seven major environmental laws. This would be especially beneficial for hazardous waste monitoring because of the multimedia nature of the risks.

8. Public opposition to siting of waste facilities stems from fears of health or safety effects, fears of economic loss, uncertainty of industry's ability to prevent adverse consequences, and lack of confidence in government regulations and enforcement.

9. Technical approaches to address public concerns include development of a comprehensive hazardous waste management plan, establishment of technical siting criteria, identifying a bank of suitable sites, and fostering open exchange of technical information (particularly on alternatives to land disposal) between the public, government officials, and the hazardous waste management industry.

10. Nontechnical approaches include assurance of public participation in siting decisions, compensation for victims of damage, a clear commitment by government to enforcement of regulation, and possibly, incentives for communities to accept proposed facilities.

11. The Federal role in answering public concerns might be expanded in several areas:
    - providing technical expertise for development of siting criteria and programs,
    - consideration of federally owned lands as suitable sites,
    - encouraging information exchange,
    - serving as arbitrator in disputes, and
    - assisting in the development of regional compacts for hazardous waste management.

Risk Management

Throughout history, people have had to find ways of coping with old and new risks. Most individuals are risk-averse and their responses to new risks may be to:

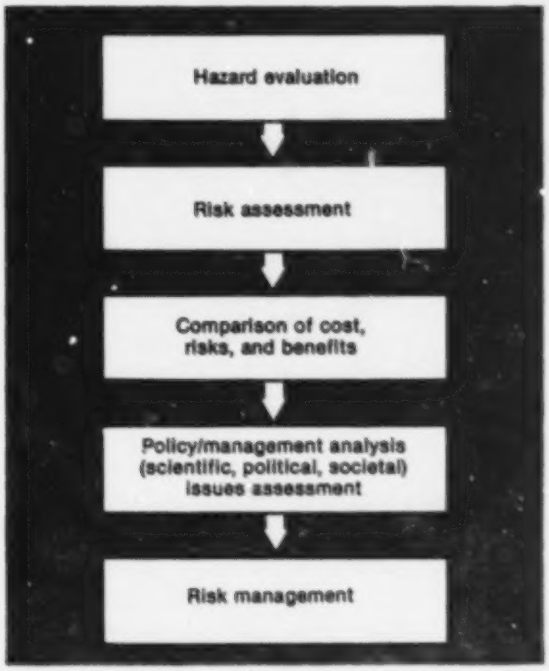
- retreat from it—attempting to return to a safer, more predictable environment,
- try to understand it—measuring the probability that a damaging event will occur and identifying risk/benefit tradeoffs,
- control it—applying various technical solutions, and
- prepare for it economically—insuring against the occurrence of the damaging event.

While these responses can help individuals and societies to cope with risks, none can produce a totally predictable or safe world. There is no such thing as zero risk. Risks must be assessed and courses of action decided. Individuals do this informally and often automatically. More formal decisionmaking usually is required in assessing risks for society.

Managing the risks from industrial hazardous waste is a highly complex task because of the diverse range of hazards involved and the many possible ways of handling the waste. Thus, a managerial framework is needed within which an expanding knowledge base can be accommodated and the risks of alternate courses of action analyzed. Figure 14 shows the major components of such a framework.

The framework illustrates a systematic way of proceeding from evaluation of hazards, through risk assessment and a weighing of risks, costs, and benefits, to a final policy choice that includes consideration of value judgments and political factors. As discussed in detail below, there are uncertainties in this

Figure 14.—Risk Management Framework


Hazard evaluation
Risk assessment
Comparison of cost, risks, and benefits
Policy/management analysis (scientific, political, societal) issues assessment
Risk management

SOURCE: Office of Technology Assessment.

process from the earlier steps based on scientific data as well as in the last, frankly judgmental, stage of policy decision. Quantitative estimates, such as those used in risk assessments, are helpful to decisionmakers. Indeed, "objective" measurement of risk is increasingly in demand by the regulated industries, public interest groups, and policymakers. **But it is a mistake to accept numerical estimates generated by risk assessments uncritically. Decisionmakers must recognize that, at the current state of the art, all risk estimates inevitably contain uncertain data and debatable scientific assumptions.**

Hazard Evaluation

The terms **hazard** and **risk** are often used interchangeably. This report maintains a distinction between them. **Hazard is defined as the inherent capacity to cause harm.** Harm could be physical damage (e.g., fire, corrosion, or explosion) or biological impairment resulting in the illness or death of an organism. Hazard evaluation concentrates on:

- the capacity to cause adverse effects, and
- the severity of that effect.

Hazard evaluation includes consideration of toxicological factors* as well as the transport and ultimate fate of materials in the environment. Hazard evaluation emphasizes probable causes and effects and explores possible worst-case effects on human beings, plants, and animals. At this first step in the decision framework, no attempt is made to quantify the probability that an effect indeed will occur.

Risk Assessment

Risk is defined as the probability that a given hazard will cause harm, of a specified nature and intensity, to a human population or ecosystem. For hazardous waste management, risk assessment means calculating the probability that constituents of a waste released from a facility will cause specified adverse effects to public health or the environment. The assessment assigns numerical risk values to the events that it analyzes.

Risk assessment consists of two stages:

- estimation of the risk value, and
- validation of that estimate.

In the first stage, quantitative probability estimates are made about the likelihood that a particular cause will lead to a specific effect. These estimates are based on the results of hazard evaluations and an identification of exposure routes that, in turn, suggest the populations or ecosystems at risk. Estimating exposures and the dose of a hazardous material that will have a particular effect is extremely difficult; this difficulty is not always acknowledged.

The second stage of risk assessment acknowledges its uncertainties and attempts to put the calculated value in a proper perspective. The validation stage uses statistical procedures to give some indication of the confidence one can have in the risk estimate. Uncertainties do not invalidate the use of risk estimates in decision-making, but it is important to keep the confidence levels in mind. Too often, confidence levels are either deemphasized or ignored as the risk estimate is carried through the remaining steps of risk management.

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*These toxicological factors are discussed in the next section, "Classification Systems."

The uncertainties of risk estimation result from the basic imprecision of hazard evaluation. The hazard may not be verified and exposure routes may be questionable; there may even be uncertainty as to whether a release will actually occur. An additional complication is that direct evidence of cause and effect between human exposure to harmful agents and damage to health is elusive.

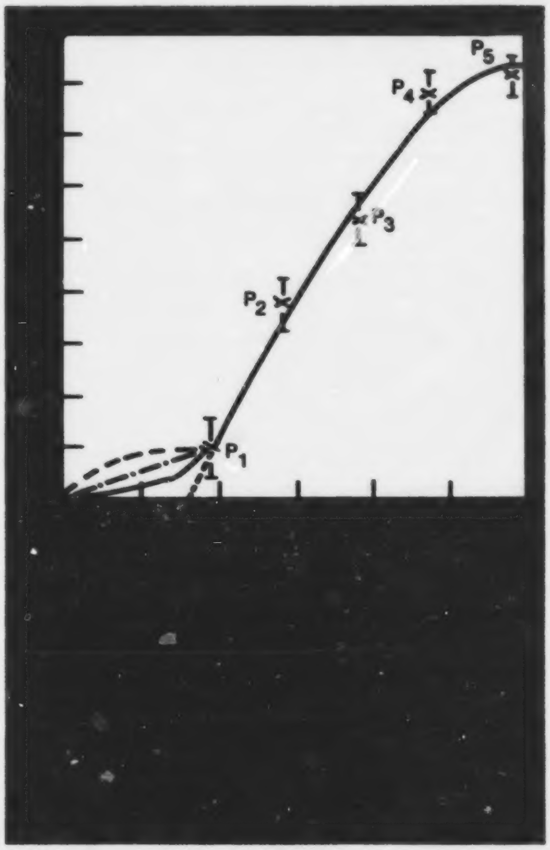
Assessment Models

Little scientific information now available indicate with any certainty the existence of cause-effect relationships between industrial hazardous waste and human health problems. Even with the amount of exposure documented for residents at Love Canal, the relationship between the exposure and health problems is not readily apparent at this time.[1] [2] Thus, the data used in risk assessments are usually obtained from experiments with laboratory animals and environmental systems. The experimental data are used to develop quantitative estimates for other species through extrapolation.

These extrapolations have been criticized as not always reflective of actual exposures. Some consider it unwarranted to apply data from animal experiments using high doses to estimate risks to human beings and the environment from exposure to low doses. The main reason for experimental use of high doses is economic. Using low-dose exposures to obtain reliable data would require tests with tens of thousands of laboratory animals. Critics of animal data argue that because laboratory tests are conducted with specially bred animals, often originating from a single set of parents, the animals may not react to the exposure in the same way as humans or as organisms found in the natural environment. While such criticisms may be appropriate, they are also simplistic. Well-established human data are usually absent. Extrapolations from animal data are an inherent and unavoidable process for establishing acceptable levels of risk.

Dose-response curves are used to extrapolate the probabilities of response from experimental high-dose data to low doses. A stylized dose-response curve is presented in figure 15. Several mathematical models are available for ex-

Figure 15.—Stylized Dose-Response Curve With Extrapolation to Low Doses Using Different Models



SOURCE: Office of Technology Assessment, 1981.

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[1] Environmental Protection Agency, *Environmental Monitoring at Love Canal*, 1981, pp. 1404-1407.

[2] D. T. Janerich, et al., "Cancer Incidence in the Love Canal Area," *Science* vol. 212, 1981, pp. 1404-1407.

trapolating incidences for the low-dose range on such a curve (i.e., below 1D, as shown in the figure). These models are based on combinations of biological theory, experimental evidence, and statistical conventions.[3] As the figure shows, the predictions of different models for the probable incidence of low-dose effects can vary considerably. For example, risk estimates for a dose level of 1/2D (with D representing the standard dose) vary between 0 and 10 percent. Because of the very large number of animals required to test the theories behind these models, none of them have been scientifically verified. Thus, the risk value at low doses is very dependent **not on actual dose-response data, but on choice of methodology.**

Human experiments, providing direct evidence of damage to human health as a result of exposure to an agent, are rarely done for obvious ethical reasons. Evidence about human exposures and effects is drawn instead from epidemiological studies, which are beset with certain difficulties. Often the population size in an epidemiologic study is small. Moreover, identifying the actual dose and duration of exposures to a particular compound has problems. Because humans are exposed to a multiplicity of materials, it is difficult to determine that one particular compound or hazard is the **only** major cause of an effect. The mobility of the U.S. population adds to the problem. Americans relocate often, and few are exposed to the same environmental conditions for enough time to indicate cause-effect relationships. The difficulty of identifying cause-effect relationships also is compounded by the long-time lags between exposure and onset of many health problems (i.e., decades rather than months or days). Even for cancer or circulatory diseases, both subjects of concerted research attention, absolute certainty about causal relationships—that smoking causes lung cancer or that saturated fat damages the circulatory system—may not be universally accepted.

Limited data exist showing a relation between exposure to waste constituents in the workplace and health problems of workers. Even these data, however, do not indicate with certainty that a relationship between hazardous waste and health problems exists. For example, if exposures in the work environment are well defined and the health problem is otherwise rare, the causal relationship may be beyond question. An example is the relation between occupational exposure to vinyl chloride and angiosarcoma of the liver.[4] However, if the environment of the workplace is complex (e.g., multiconstituent exposures) it may be difficult to establish a causal relation between the presence of a single compound and a particular health effect. Extrapolation from these workplace exposure data has problems similar to those for extrapolating from animal data; concentrations of hazardous constituents in the workplace are usually considerably greater than in the general environment.

Recently interest has grown in determining relative risks rather than calculating specific risk estimates. Relative risks are derived from computer models that combine a variety of factors to simulate real situations (e.g., risks associated with a waste at a facility location on a particular site). Such assessments have been developed for ranking uncontrolled hazardous waste sites needing remedial action under the Comprehensive Environmental, Response, Compensation, and Liability Act of 1980 (CERCLA). They are also being used to assess risks associated with specific wastes, particular environments, and individual technologies for the purpose of improving regulation under the Resource Conservation and Recovery Act (RCRA). The use of such models is attractive, since risk scores for different situations can be compared on the basis of common indicators without resorting to extrapolation models.

Appropriate Uses of Risk Assessment Models

As long as extrapolation models incorporate exposure doses that are close to those used in experiments, any conceptual errors in extrapolation procedures usually have only minor impacts. However, as the estimates of exposure doses move farther and farther from the experimental data, results of the model become more and more critically dependent on the validity of the scientific theory describing chemical-organism interactions, contained in the model. Thus, as the distance from experimental data increases, the predictive power of the models decreases.

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[3] For a discussion of these models see *Technologies for Determining Cancer Risks From the Environment* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-H-138, June 1981).

[4] R. R. Monson, "Effects of Industrial Environment on Health," *Environmental Law*, vol. 8, 1978, pp. 664-700.

The major goal of some extrapolations may not be accuracy of prediction, but **assurance of adequate protection.** For such purposes, the extrapolation model selected is conservative and predicts the greatest risk for lowest possible doses. When establishing protective limits, a poorer data base is usually associated with larger "safety" or "uncertainty" factors. Thus, risk estimates derived from uncertain data but assuring a high level of protection could be much greater than estimates based on more accurate prediction of health effects if such a prediction were available. It should be emphasized that most results of extrapolation currently published represent **protective** estimates. Unfortunately, these conservative estimates are often interpreted as predictions of incidence. When protective estimates are published or used in decisionmaking, they should be accompanied by a clear statement of the uncertainties they contain. Recent advances in the field of risk assessment are improving the precision and accuracy of predictive models. Significant progress is being made in extrapolations between: species, differences of time of exposure to effect, and different doses and response levels.

The use of computerized models can be appropriate for developing governmental priorities and policies. However, the limitations of these tools must always be recognized. Although the best models can only provide an abstraction of real conditions, three factors can contribute to more reliable results:

1. **The indicators for risk should be relevant to actual exposure situations and should assist in identifying populations at risk.** These indicators should not be arbitrarily chosen but should reflect as nearly as possible the range of hazards of the constituents of concern, the environmental fate of constituents, and realistic exposure factors.
2. **The data base should include accurate and verified information insofar as possible.** Every attempt should be made to obtain valid data. Uncertainties in data precision should be identified.
3. **Biases incorporated in the model either through the choice of assumptions or the assignment of quantitative values to risks should be identified and the effects of these biases assessed.** To give analyses using risk assessment proper weight, policymakers must be aware of the biases inherent in the models. If risk assessments are used in the description and evaluation of alternative options, it is essential to provide **sensitivity analyses,** showing the differences in risk values that result from changes in basic model assumptions and data bases.

Risk assessments can contribute to a variety of specific decisionmaking purposes. They can be used in setting forth regulatory standards, establishing priorities for research and development (R&D), identifying the risk levels of various disposal/treatment options, and determining appropriate locations for waste management facilities. Although progress continues in risk assessment methodologies, the quantitative estimates they produce are imperfect, and must not be used uncritically.

Comparison of Risk, Costs, and Benefits

The two stages of risk assessment are intermediate steps in the total risk-management framework, which also involves comparing the risks, benefits, and costs in various management alternatives. Different approaches can be used in making such comparisons. They include evaluation of relative risks among various options, comparing risks with benefits, or concentration on costs by evaluating either cost effectiveness or costs and benefits of management options.

1. **Relative risks.**—Risk estimates (either probability values or relative risk scores) for one option are compared with risks of another. For example, comparisons can be made between risks from land disposal and risks from incineration of a particular industrial waste stream.
2. **Risk benefit.**—This approach compares risks of an option with some expression of expected benefits, with the aim of maximizing benefits and minimizing risks. Different options then can be compared on the basis of relative risks and benefits. For example, risks and benefits of biological treatment of organic waste can be compared with risks and benefits of incineration of the same type of waste.
3. **Cost effectiveness.**—In this assessment method, a fixed goal is established and policy options are analyzed on the ability to achieve that goal in the most cost-effective manner. The goal is generally a certain level of acceptable risk and the options are compared on the basis of the dollar value necessary to reach that level of risk. Cost constraints can also be imposed so that the options are assessed on the ability to control the risk most effectively for that set cost.
4. **Cost benefit.**—This approach expands the risk-benefit framework to evaluate risk and benefit outcomes in dollar values. This method requires more information than any of the others and forces quantification of benefits, even when such quantification may not be accurate or valid.

The language of individual laws may dictate which risk-management approach can be used in regulation.[5] In the 21 statutes that regulate production, commercial distribution, and disposal of potential carcinogens, some specify protection of health "to the extent possible." Other statutes restrict agencies to consideration of effects only. For example, RCRA states that the Environmental Protection Agency (EPA) ". . . shall promulgate regulations establishing standards . . . **as may be necessary to protect human health and the environment,**" thus constraining EPA from use of cost-benefit comparisons.

Although both Congress and the executive branch have expressed interest in cost-benefit analyses (CBA), there is some controversy about the extent of its use. Most experts agree that CBA does serve a useful purpose but caution against unlimited applications.[6] [7] [8]

Among the limitations are, first, the problems of expressing both cost and benefit values in dollar terms. George Eads, former member of the Council of Economic Advisors, recently stated:[9]

> The numbers casually tossed about by interested firms and industries no more represent the true cost of regulation than the overblown claims by regulation supporters reflect the likely actual benefits.

The reasons for the overestimates in cost are:

- economies of scale, which arise when the demand for hazard control technology increases, are often ignored;
- learning curves, which reflect increasingly sophisticated industrial responses to regulatory requirements, are not anticipated; and
- the role of technological innovation as a factor in reducing costs is often not given proper attention.

Benefit values expressed in dollar terms also are often questionable. There is little agreement among experts using CBA on the appropriate dollar value to assign to human life or to society's willingness to pay for some perceived benefit. Thus, these values are dependent on the individual judgments made by an analyst, and will differ among analysts. Some benefits, such as improved quality of life, are very difficult to quantify.

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[5] J. P. Leape, "Quantitative Risk Assessment in Regulation of Environmental Carcinogens," *Harvard Environmental Law Review*, vol. 4, 1980, pp. 86-116.

[6] R. W. Crandall, "The Use of Cost-Benefit Analysis in Regulatory Decisionmaking," *Management of Assessed Risk for Carcinogens* (New York: N.Y. Academy of Sciences, 1981), pp. 99-107.

[7] M. S. Baram, "The Use of Cost-Benefit Analysis in Regulatory Decisionmaking is Proving Harmful to Public Health," *Management of Assessed Risk for Carcinogens* (New York: N.Y. Academy of Sciences, 1981), pp. 123-128.

[8] W. H. Rodgers, Jr., "Benefits, Costs, and Risks: Oversight of Health and Environmental Decisionmaking," *Harvard Environmental Law Review*, vol. 4, 1980, pp. 119-226.

[9] G. C. Eads, "Research in Regulation, Past Contributions and Future Needs," *Attacking Regulatory Problems, An Agenda for Research in the 1980s* (New York: Ballinger Press, 1981), pp. 1-18.

A second limitation concerns the deceptive nature of cost-benefit methodology. The use of quantitative techniques may give the nonexpert an unjustified impression of neutrality and certainty. This impression is, of course, incorrect. As detailed above, the uncertainties surrounding risk assessment are numerous, and the dollar values assigned to costs and benefits reflect value judgments. For example, in applying CBA to hazardous waste management, a critical problem is the lack of information concerning the nature of risks in inappropriate disposal/treatment practices.[10] Assigning dollar values for unknown risks or benefits is of little value.

Much of the work in risk management has concentrated on the costs and benefits of controlling pollution to meet certain environmental standards (e.g., the cost of pollution control equipment and benefits of reduced health problems). Many analysts argue that for the purposes of risk management where specific benefits (e.g., protection of human health and the environment) are desired or mandated, the most appropriate methodology is **cost-effectiveness** comparisons. This seems particularly appropriate for hazardous waste management.

Policy/Management Decisions

Once hazard evaluations, risk assessment, and comparisons of risk, benefit, and cost have been completed, the results can be used to reach risk-management decisions. It must be emphasized **that these steps in the decision framework are only tools to aid in analysis of alternative policy choices; the results are not the risk-management decision itself.** In making policy or management decisions, many factors beyond these quantitative results must be considered. The decisionmaker must evaluate uncertainties, identify value judgments, recognize special interests, and consider political factors. As risk-management, decision-analysis proceeds, conflicts will arise. These conflicts have no right or wrong solutions. They represent differences in societal interests and perspectives and must be considered in the decisionmaking process.

Formalized approaches for making choices in complex situations, known as decision analysis, exist.[11] [12] Decision analysis is designed to help decisionmakers choose from a set of specified alternatives in a systematic manner. Most risk-management situations involve large volumes of data, multiple conflicting objectives, and the unavoidable use of subjective judgments. If, in addition, adversary positions complicate the matter, a systematic approach can be very helpful in reaching appropriate solutions. Hazardous waste management is just such a situation.[13] The use of decision analysis here might have merit. Most designs for multiattribute decision analyses do not incorporate estimates of risk, but there is no reason why risk assessment cannot be integrated into the technique.

When risk assessment is brought into policy decisions, it is important to identify all uncertainties and to couch the results with appropriate caveats that explain the limitations of the analysis. Risk assessment can be a useful tool for making broad decisions, if the choice of the appropriate methodology is well considered and the uncertainties in each of the alternative solutions clearly recognized.

Because the need for a better data base is critical to meaningful policy decisions, it is often implied that tradeoffs must be made between expeditious protection of public health and the need to obtain improved data before decisions can be made. This conclusion appears too pessimistic. Granted, present methods for deriving quantitative components in the risk-management framework are by no means perfectly developed. Nonetheless, with careful analysis of available data, existing tools can be used effectively. R&D should continue to improve risk-assessment methodologies. Integration of these tools in a multiattribute decision framework would provide a systematic approach for risk management in a hazardous waste regulatory program. The use of such a framework also would provide a means for open scrutiny of all aspects of a decision.

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[10] R. C. Anderson and R. C. Dower, "The Use of Cost-Benefit Analysis for Hazardous Waste Management," *Disposal of Hazardous Waste*, EPA 6th Annual Research Symposium (Washington, D.C.: Environmental Protection Agency, 1980), pp. 145-166.

[11] R. L. Keeney and H. Raiffa, *Decisions With Multiple Objectives: Preferences and Value Tradeoffs* (New York: John Wiley & Sons, 1976).

[12] K. R. MacCrimmon and J. K. Siu, "Making Trade-Offs," *Decision Sciences*, 5, 1974, pp. 680-704.

[13] T. H. Ess and C. S. Shik, "Multiattribute Decisionmaking for Remedial Action at Hazardous Waste Sites," in *Risk and Decision Analysis for Hazardous Waste Disposal* (Silver Spring, Md.: Hazardous Materials Control Research Institute, 1981), pp. 196-209.

Classification Systems

RCRA regulations for the management of hazardous waste do not recognize differences in the level of risk associated with various waste and management technologies. Regulation based on degree of hazard has an obvious appeal. Few dispute its theoretical advantages. At issue, however, is the level of detail required to regulate waste management by some method of classification, and whether the expected improvements would be great enough to justify the time, people, and money needed to develop a classification approach.

The challenge is to design a system that reflects real conditions. A design that is too simple would not represent the actual hazard posed by waste or the potential risk level from particular facilities. A more complex system might better represent the waste management situation. However, as the level of complexity increases, so does the need for extensive data development. Thus, the usefulness of a complex system may be questioned if it imposes greater burdens on industry (e.g., in furnishing large amounts of data on waste and facility characteristics) and on government (e.g., in enforcing submission of data by industry and verifying the data).

In the past, several States have considered hazard classification as a means of regulating industrial waste. A majority of those States submitting comments on the 1978 proposed regulations urged EPA to consider development of a formal classification system based on degrees of hazard.[14] The fact that States are interested in this concept and have attempted to include waste classification systems in their management programs suggests that further consideration at the Federal level might be justified.

Although most discussions of classification systems have focused only on categorizing waste by levels of hazard, an effective risk-management system must also include classification of the facilities handling the waste. Without consideration of both hazard and risks associated with all management options, optimal protection of public health and the environment will not be possible.

Waste Classification

A basic premise of a waste classification system is that a waste or its constituents can be grouped according to criteria that define quantifiable human and environmental effects. The principal distinction is between those wastes that pose a substantial threat to human health and the environment and those posing relatively less harm.

Technical Background

For industrial waste, hazard refers to those characteristics inherent to a specific waste or its constituents that could cause adverse effects in humans and other organisms. The hazard characteristics of concern in the RCRA regulatory programs are ignitability, corrosiveness, reactivity, and toxicity. Table 40 provides definitions of these four types of hazard, the commonly applied test indicators for each, and an indication of whether discrimination among hazard levels is possible.[15]

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[14] *The RCRA Exemption for Small Volume Hazardous Waste Generators* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, 1982).

The information needed to evaluate degrees of hazard of different materials is illustrated in figure 16 and include:

- specific process waste and their constituents,
- toxicological characteristics, and
- chemical and physical factors that influence their environmental fate.

Specific Process Wastes.—In general, a waste from a single industrial process is composed of more than one type of chemical. Identification of the major constituents is needed to determine ignitability, reactivity, corrosiveness, and toxicity. The concentrations of major constituents also must be known, since these will determine the dose available to organisms. The physical state of the waste (e.g., liquid, sludge, solid, gas) influences potential levels of hazard by affecting potential routes of exposures. For example, if the waste is predominantly liquid, it may migrate through the environment more rapidly than if it were solid. The physical state of individual constituents is important as well; the harm posed by some compounds varies according to the extent of molecular complexity, or isomerization. For example, less chlorinated forms of PCBs (e.g., mono-, di-, and trichlorobiphenyl) pose less harm than the more chlorinated forms (e.g., penta-, hexa-, and decachlorobiphenyl). Also, the electric charge, or valence of ions influences chemical interactions (e.g., different valence levels of iron, Fe^{++} and Fe^{+++} react differently). Obtaining this information is not difficult. Accurate estimates of waste composition, physical form, and concentration of major constituents of a process waste can be derived by an analysis of feedstock information and of the reactions taking place during manufacture.

Table 40.—Waste Characteristics That May Pose a Hazard

Hazard definition	Commonly used indicators	Potential for hazard classification
Ignitability		
Direct—exposure to heat, smoke, fumes; indirect—dispersion of hazardous byproducts	Flash point, fire point autoignition temperature	Classification scheme used by the Department of the Interior and National Fire Protection Association; could use composition limits of ignitability, flash point, and ability to sustain combustion as criteria
Corrosivity		
Direct—destruction of living (tissue) and nonliving surfaces; indirect—influences solubility and transport of hazardous compounds	pH level—acid or base	pH expressed in logarithmic scale; could use pH, buffering capability, ionization potential, rate of corrosion of standard material (steel)
Reactivity		
Direct—evolution of heat, pressure, gases, vapors, fumes; indirect—encompasses several aspects of chemical reactions when compound/solutions are mixed or initially interact	"Violent" reaction with water	Difficult to distinguish degrees of reactivity
Toxicity		
Produces adverse effect (e.g., death or nonreversible changes in living organisms)	Range of acute and chronic test results	Classification schemes have been developed by several States for managing either toxic substances or hazardous waste

SOURCE: Daniels, 1981.

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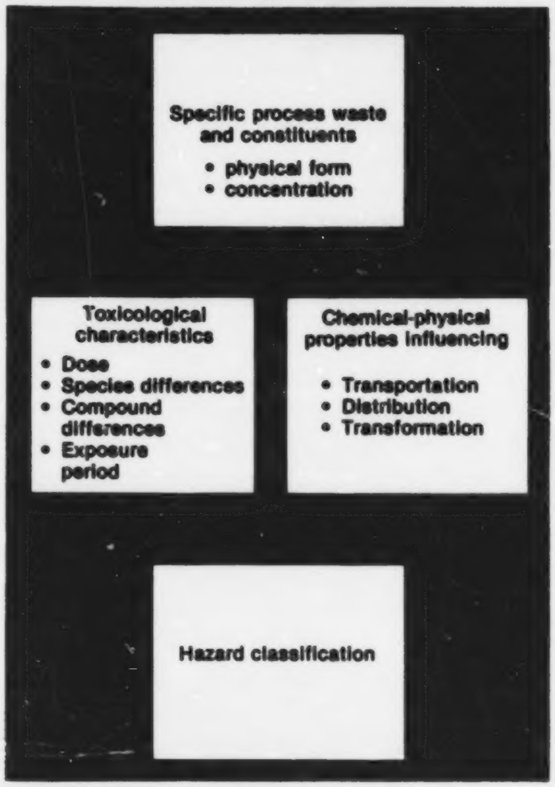
[15] S. L. Daniels, "Development of Realistic Tests for Effects and Exposures of Solid Wastes," *Hazardous Solid Waste Testing* (Philadelphia, Penn.: American Society for Testing and Materials, 1981), pp. 345-365.

Figure 16.—Information Requirements for Hazardous Waste Classification



SOURCE: Office of Technology Assessment.

Toxicological Characteristics.—The effects of industrial waste on humans and the environment range from innocuous, short-term impacts such as a mild skin rash to severe long-term problems like cancer. Four factors are important in determining the toxicity of a substance: dosage, species affected, type of compound, exposure period, and route.

1. **Dose.**—The 15th century alchemist Paracelsus noted: "All substances are poison; the right dose differentiates a poison and a remedy." Dose is defined as a selected concentration of a substance or mixture of compounds administered over a specific period of time. For any material there is a dose that will produce adverse effects in a given organism. Similarly, there is a concentration sufficiently low that no adverse effect can be observed (i.e., the response observed in a test population cannot be distinguished from normal background incidences). Even the most innocuous compound (e.g., water), if taken into an organism in sufficient quantity, can result in some undesirable effect or death. A very harmful material (e.g., PCB) can be administered in a dose sufficiently low that no adverse effects can be observed. Concentrations of specific constituents within a waste provides a first, and possibly a worst case, approximation of the potential dose available to organisms.
2. **Species differences.**—The dose of a specific chemical required to cause some effect (e.g., death) will vary among species (e.g., monkey, dog, and human). For example, when laboratory animals are exposed to air contaminated with cyanogen, the dose required to produce an acute toxic effect varies—cats can only tolerate doses up to 98 parts per million (ppm), but rabbits do not experience toxic effects below 395 ppm.[16] Dosages that produce chronic effects also can vary among species. For example, the amount of Aroclor 1254 that results in some adverse effects on reproductive systems is 200 milligrams per kilogram (mg/kg) for pheasants, 10 mg/kg for mink, and 50 mg/kg for chickens.[17] The quality of the effects also vary among these species. In addition, individuals within a species respond differently to the same concentrations because of such factors as age, stress, and natural sensitivities. For example, nitrates in water can be ingested by an adult human with no adverse effect, but the same nitrates are toxic to infants at certain concentrations.
3. **Compound differences.**—The dose required to produce a given effect (e.g., death) in a given species (e.g., rats) varies with the type of compound being tested. Examples of differences in acute toxicity

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[16] *Registry of Toxic Effects of Chemical Substances* (Washington, D.C.: U.S. Department of Health, Education and Welfare, 1980).

[17] National Research Council, *Polychlorinated Biphenyls* (Washington, D.C.: National Academy of Sciences, 1979).

are presented in table 41.[18] In these examples, the amount required to produce death in 50 percent of the test population varies greatly, ranging from 3 mg/kg for cyanide to 5,000 mg/kg for toluene.[19] Although these compounds vary greatly in acute toxicity, EPA has designed them as equally hazardous on the basis of a number of factors, including toxicity, carcinogenicity, mutagenicity, and teratogenicity.[20]

Just as the degree of acute toxicity is not equal among all compounds, doses for chronic toxicity can vary also; for example, not all carcinogens are equally potent.[21] [22] In particular, Crouch and Wilson note that:

> . . . certain of the known carcinogens are intrinsically much more likely than others to cause cancer in test animals—they are more potent. The variation in potency may be as great as a million to one between different materials (depending to some extent on the definition used for potency). A small amount of aflatoxin B1 in the diet (100 parts/billion) gives cancer to a large fraction of the animals exposed, yet the same amount of saccharin in the diet causes no observable effect.

Table 41.—Toxic Doses for Selected Hazardous Waste Constituents

Compound	LD_{50}[a]
Cyanide	3
Phenylmercuric acetate	30
Dieldrin	46
Pentachlorophenol	50
DDT	113
Naphthalene	1,780
Toluene	5,000

[a] Amount (mg/kg body weight) that is lethal for 50 percent of the test population, in these examples following oral administration to rats.

SOURCE: Office of Technology Assessment, 1981.

4. **Exposure period and route.**—Exposure to hazardous waste constituents can result from either expected* or unexpected releases to the environment. Releases of hazardous waste constituents can be continuous or intermittent and can go into air, soil, or water. The quality of a response to a waste constituent will depend on the route of exposure and the duration of exposure. For example, a large concentration given all at one time can result in severe effects including death. In contrast, harmful effects may be much less serious or not observed at all when the same amount is given over several days or a longer period.

   Also, the route of the exposure influences the quality of the effect. For example, some compounds are toxic if inhaled but produce no effect if ingested or if applied to the skin (e.g., fine-grained silica sand). The importance of exposure factors is recognized in regulation; different standards define different permissible levels of compounds in food, water, and air.

Chemical and Physical Factors Determine Environmental Fate.—Chemical and physical properties of waste determine both the movement of constituents through the environment and the incorporation of these materials into living and inanimate elements. Some of these properties are solubility, volatility, physical state (e.g., liquid or solid), pH (level of acidity), and adsorbancy characteristics. Because of their particular chemical and physical properties, some compounds may migrate rapidly through soil and air but accumulate in water sources. Others may bind strongly with soil particles and remain isolated from vegetation or other organisms. Still others may be incorporated into plant and animal tissue and become distributed throughout food chains. Such transfer and distribution of waste constituents is also influenced by physical conditions of environmental media (e.g., type of soil and climatic conditions).

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[18] *Nonnuclear Industrial Hazardous Waste: Classifying for Hazard Management—A Technical Memorandum* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-TM-M-9, November 1981).

[19] *Registry of Toxic Effects of Chemical Substances*, op cit.

[20] 40 CFR, section 261, subpts. B,C,D, and app. VIII.

[21] E. Crouch and R. Wilson, "Regulation of Carcinogens," *Risk Analysis in Environmental Health* (Cambridge, Mass.: Harvard School of Public Health, Short Course, 1982).

[22] R. A. Squire, "Ranking Animal Carcinogens: A Proposed Regulatory Approach," *Science*, vol. 214, 1981, pp. 877-880.

*Releases from waste disposal and treatment facilities will depend on engineering design. For example, the release rate from an incinerator is influenced by the combustion efficiencies of a particular facility. For land disposal units this rate depends on the amount of liquid disposed as well as types of covers and liners. See ch. 5 for a discussion of various engineering designs.

As a compound migrates through air, water, soil, and biota, changes in its structure can occur because of chemical, photochemical, and biochemical reactions. These changes may result in the complete destruction of the hazardous characteristic of a waste constituent, eliminating any threat to health and the environment. However, it is also possible that new, more hazardous compounds can result. The structural changes need not be large, even small rearrangements in molecular structures can influence either accumulation of a compound in tissue or its degradation.

Models for Classification of Waste

The degree of hazard of a specific waste or its constituents can be determined by analyzing data on the state of the waste, toxicity, environmental fate, and safety. Table 42 lists certain important factors in establishing criteria for waste classification. Categorizing materials on the basis of measures of hazard is not a novel concept. Several methods have been developed. These include formal classification systems and rank-order models.

Formal classification models categorize waste constituents according to toxicological criteria or to a combination of toxicity factors, measures of environmental fate, and concentrations of waste constituents.[23] Threshold values are assigned for each criteria. In order to keep the systems simple and usable, most of these models rely only on measures of acute toxicity and identification of materials known or suspected to be carcinogenic. These criteria are rather limited for judging the overall hazard of a waste or its individual constituents.

Rank-order models were developed in response to the mandates of the Toxic Substances Control Act (TSCA).[24] Compounds of concern are assigned a separate score for each of several different criteria. The overall ranking is based on a combination of these scores. Included is a broad range of factors: acute toxicity, carcinogenicity, mutagenicity, teratogenicity, persistence, bioaccumulation, esthetics, and chronic adverse effects. A modification of these rank-order models incorporates an additional concept, commonly termed "red-flagging."[25] Within each criterion a minimum score, termed a discriminatory value, is identified. This value serves to flag those chemicals that may pose severe threats to health and the environment.

To date, rank-order models have been used only to set priorities for actions affecting chemicals, rather than to establish classes of hazard. It has been suggested that the system can be used for ranking compounds by their carcinogenic potency for regulatory purposes.[26] Also, Michigan has developed a rank-order model to provide a way of identifying

Table 42.—Factors Important for Hazard Classification Criteria

Hazard characteristics	Measures to distinguish category boundaries
Physical data:	
State of waste	Solid, liquid, gas, vapor, mixture, etc.
Concentrations	Percent of total waste stream, actual measurement
Toxicity:	
Acute toxicity	Short-term responses, e.g., lethal dose ranges for terrestrial and aquatic species
Chronic toxicity	Long-term responses, e.g., severity of morphological and functional impairments
Genetic impairment	Carcinogenic and mutagenic potency
Environmental fate:	
Persistence/degradation	Half-life in soil, air, and water
Bioaccumulation	Affinity for water or lipids in tissue
Exposure potential	Distribution and partitioning parameters—solubility, volatility, sorption
Safety:	
Ignitability	Flash points, combustibility
Corrosivity	pH ranges, buffering capacity
Reactivity	Immediate adverse (explosion) reaction with water or release of significant quantities of water

SOURCE: Office of Technology Assessment.

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[23] Appendix 6 presents examples of classification schemes developed by various States. For a discussion of each, see *Nonnuclear Industrial Hazardous Waste: Classifying for Hazard Management—A Technical Memorandum*, op. cit.

[24] Public Law 94-469, 1976.

[25] S. L. Brown, "Appendix B. Systems for Rapid Ranking of Environmental Pollutants," *Scoring Chemicals for Health and Ecological Effects Testing* (Rockville, Md.: Enviro Control, Inc., 1979).

[26] Squire, op. cit.

critical materials that may require the attention of State officials.[27]

Although rank-order models were not developed for classification of industrial waste, they might be adapted for such use. Critical factors contributing to the inherent hazard of a waste could be identified and an appropriate range of scores defined for each factor. Ranges of total scores could be grouped into hazard categories. Both hazard potential and environmental fate factors can be readily incorporated into the system.

Waste classification systems have certain problems that must be resolved. First, most of the available models rely heavily on measures of acute (short-term) toxicity and carcinogenicity. While these two criteria may be important, there are other chronic (long-term) health effects and environmental impacts that should receive equal attention. The problem is that there are few reliable ways to measure such chronic effects as reproductive impairment, immuno-suppression, and physiological dysfunction or damage of organs (e.g., heart, lung, and liver). Criteria for these effects could be developed on the basis of animal experiments used to approximate human impacts, but data even from animal tests are scanty. Obtaining them will require long-term testing for several years. No reliable short-term procedures exist for measuring these chronic effects. Short-term bioassays for mutagenicity and genetic impairments are used as rough measures of propensity to cause cancer, but they do not always correlate with the results of longer term tests for cancer. Determining criteria for environmental effects is in its infancy. (This became a concern only with the passage of TSCA.) While some testing methodologies are available, considerable development work lies ahead.

A second problem arises from the analysis of individual constituents as a measure of the hazard of a waste. It may not be prudent to assume that the actual hazard posed by any particular waste is the same as the "collective hazard" of individual constituents. Most hazard models do not consider synergistic or antagonistic effects, nor do they evaluate degradation products, and possible major interactions. Some proponents of classification would argue that individual constituent analyses provide a conservative estimate of a hazard, but may not necessarily be true. Such an analysis may suggest medium or low hazard; if compounds interact, however, the actual hazard of a waste could be high. Some compounds that do not, individually, produce cancer in exposed animals, will do so in combination. Also, while a parent compound may be low in hazard, the degradation products could be more hazardous; degradation of certain compounds to nitrosamines is an example.

Finally, given the uncertainties in the analysis of hazards, a test result for any compound always will have a certain level of error associated with it. Discrepancies in hazard classification can result and must be addressed. If they are ignored, they could lead to endless litigation between waste generators and EPA over whether a waste really is highly hazardous or merely represents medium hazard. For example, an "extremely hazardous" criterion might be set at less than 50 mg/kg (the lethal dose for half the exposed population) for oral administration to mammals. Then questions might be raised if a waste with test results of 49 ± 4 mg/kg is assigned to the extremely hazardous category. The questions could multiply if the test results for the waste were 49 for rats, 100 for mice, and 500 for dogs. While none of these species has exact correlations with human effects, all are legitimate test animals.

This last problem is not unique to classification of waste. It occurs with any standard, for any material. To resolve the problem, classification boundaries must be set with clearly defined limits. A precedent for such action was set in the regulations under the Federal pesticide law[28] where EPA not only designated standards, but also established criteria for determining confidence levels of test results and guidelines for including these in evaluations of compliance.

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[27] See app. 6A for a description of each criteria used in this model. Department of Natural Resources, *Michigan Critical Materials Register* (Detroit, Mich.: State of Michigan, Environmental Protection Bureau, Environmental Services Division, 1980).

[28] The Federal Insecticide, Fungicide, and Rodenticide Act, as amended in 1978.

Facility Classification

The underlying concept for classification of waste management facilities is that the capacity to minimize release of harmful materials varies from one facility to another. Although the concept is new and highly speculative as to feasibility and design, a classification system has been proposed for management of low-level radioactive wastes.[29]

Technical Basis

The technical basis for facility classification is the concept of **risk,** defined as the probability that a defined event will occur under a specific set of conditions. In waste management, the event is the release of harmful constituents, given identified engineering designs and environmental conditions.

For each type of waste management option (e.g., thermal destruction, land disposal, and treatment facilities), ranges of design and environmental conditions can be identified. For example, the risk associated with landfills varies depending on the number of liners, the permeability of each liner, and geological conditions of the site. For thermal destruction, various designs (e.g., high-temperature incinerators, cement kilns, and boilers) offer different degrees of risk when a particular type of waste is burned. The efficiency of waste combustion is limited by process controls such as air flow, residence time, and function of the incinerator. Cement kilns, for example, can be used to incinerate certain wastes, but their original purpose is to produce cement particles. Similarly, industrial boilers are designed to produce heat, although they also can be used to incinerate waste. By contrast, the primary function of a high-temperature incinerator is destruction of combustible organics.

Determining the risk level associated with a facility design can be a complex task. The risk potential of a facility depends on more than the hazard level of the material being handled. It also depends on the type of environment surrounding a facility, meteorological factors for the site, the impact of the management option on the waste constituents (e.g., does it destroy the waste, reduce its hazard potential, sufficiently isolate it, or contain it for a specified period of time), and the technological limitations of the facility design and operating conditions.

The aim of facility classification is to match waste classes with appropriate categories of facility design and environmental conditions. For each type of facility (e.g., land disposal or incineration) an acceptable level of risk must be identified for specific environmental conditions. The match among wastes and facilities must not exceed this risk level. For example, the overall risk arising from the match of waste Class I and land disposal Class I must be the same as for waste Class II and land disposal Class II. Included in the match is the location and environment of the management facility. A waste class that would pose severe threats if allowed to escape might be managed in a facility where location and environmental conditions minimize exposure to humans and other living things.

Models for Facility Classification

Because facility classification is a new concept, few models are available for implementing the approach. Classification schemes for sites are available, but they have focused primarily on the hazard potential of abandoned dumps.[30] [31] With some modification these schemes could be applied to landfill, incineration, or treatment facilities as well.

Table 43 illustrates the type of criteria that could be used to classify management facilities.

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[29] *Striking a Balance Toward a National Policy for Managing Low-Level Radioactive Waste: Key Issues and Recommendations* (Washington, D.C.: Conservation Foundation, 1981).

[30] JRB Associates, Inc., *Methodology for Rating the Hazard Potential of Waste Disposal Sites,* prepared for the U.S. Environmental Protection Agency, 1980.

[31] Mitre Corp., *Site Ranking Model for Determining Remedial Action Priorities Among Uncontrolled Hazardous Substances Facilities* (McLean, Va.: Mitre Corp., 1981).

Table 43.—Proposed Measures for Classifying Management Options

Characteristics	Measures to distinguish categories
Design	Measures of limiting process controls (e.g., combustion levels, number of liners, sophistication of instrumentation, monitoring programs)
Meteorological	Climatic conditions
Site characteristics	Distance to nearest drinking-water well
	Distance to nearest offsite building
	Land use/zoning
	Critical environments
	Distance to nearest surface water
	Depth to ground water
	Net precipitation
	Soil permeability
	Bedrock permeability
	Depth to bedrock

SOURCE: Office of Technology Assessment.

The major factors include design characteristics, meteorological conditions, and site conditions. Appropriate design and meteorological characteristics vary with the type of facility. For example, containment capabilities adequate to the threat of floods or potential for earthquakes would be important for landfills. Incinerators would be classed according to combustion capabilities and chamber designs, together with consideration of wind patterns or air inversions. The critical environmental factors for any facility might include: distance to drinking water sources, distance to nearest population, existence of critical or endangered environments, distance to nearest surface water, depth to ground water sources, precipitation levels, soil permeability, bedrock permeability, and depth to bedrock.

Scores could be assigned for different levels within each of these factors. Separate classes may be designated based on some method of combining scores. It may be necessary to develop classification schemes based on environmental media—e.g., land (land disposal facilities), air (thermal destruction), and water (treatment facilities). The criteria could then be related to minimizing release of hazardous constituents to the relevant medium.

Once a technology/facility/site combination has been classified, waste groups then could be matched to it. Thus, a waste which is highly hazardous, moves readily through soil, and has a low potential for natural degradation would be restricted to facilities that could contain, completely destroy, or immobilize such waste. California has a scheme for classifying landfills. Permeability standards are used in conjunction with location of ground water sources to place existing landfills into one of three classes. It has recently completed a comprehensive study of hazardous waste and has restricted certain waste to particular classes of landfills.[32]

The basis for facility classification schemes is the ability of a facility to properly contain the waste for a specified period of time, and to match this period of time with rates for degradation or mobility of a waste. **Thus, facilities that can contain a waste for a specified time, or can destroy it completely (e.g., by incineration), could be selected to handle waste that are highly persistent and nondegradable.** If controlled release of the waste from a facility is likely and if there is potential for surface- or ground-water contamination at some time in the future, then the waste handled at such facility location must have degradation potentials that match the expected time of escape.

Feasibility of Classification: A Case Study

In an attempt to clarify some of the issues on classification of waste and facilities, OTA sponsored a study on the feasibility of such a system.[33] The study operated under several limitations. It used only currently available classification criteria and readily obtainable data. It examined only a selected group of hazardous wastes listed or proposed for listing by EPA for which toxicity and environmental fate data were available in EPA background documents; and it supplemented the EPA data with toxicity information from the Registry of

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[32] Department of Health Services, "Changes in Regulations of the Department of Health Services Regarding Hazardous Waste Land Disposal Restrictions (R-32- 82)," (Sacramento, Calif.: State of California, Health and Welfare Agency, 1982).

[33] J. Harris, P. Strand, and T. Shea, *Classification by Degree of Hazard for Selected Industrial Waste Streams* (Washington, D.C.: Office of Technology Assessment, Materials Program, 1982).

Toxic Effects of Chemical Substances. The goal of the study was to determine at a very simple level whether classification is possible—i.e., to test a concept that had up to then been considered only conjecture. Even given its limitations in data, the study showed that **facility classification is possible.** While the limitations of the classification models now available must be recognized, it does appear possible to improve the national hazardous waste management program through classification systems (see ch. 3).

Structure of the Feasibility Study

Two models were chosen for the feasibility study. One was a model developed by the State of Washington for use in their waste management program.[34] The other was a ranking methodology formulated by Michigan for its critical materials registry.[35] Table 44 shows the characteristics used in each system. Appendix 6A provides descriptions of how waste constituents are scored in the two systems.

Nine wastes were chosen from the RCRA list for this analysis, representing a range of volumes and toxicity levels. The wastes are shown in table 45. Because no schemes for actual management classification exist, the feasibility study reviewed only classification of landfills, using environmental criteria developed by JRB Associates.[36] The capacity to distinguish, by this means, among three existing landfills was analyzed and used to indicate the feasibility of management classification in general.

Study Results

Although EPA treats the nine wastes included in this exercise as equally hazardous, it is apparent from table 46 that further classification by degree of hazard can be made. **Even with the limited data available to the study,** it was possible to distinguish these wastes into

Table 44.—Hazard Characteristics of Case Study Classification Models

Hazard characteristic	Washington system[a]	Michigan system[b]
Physical data:		
State of waste	None	None
Concentration	Quantity/concentration formula	Quantity/concentration formula
Toxicity:		
Acute toxicity (LD_{50}, LC_{50})	Oral, aquatic	Oral, dermal, aquatic
Chronic toxicity	None	Reversible, irreversible
Genetic impairment	Carcinogenicity only	Carcinogenicity Mutagenicity Teratogenicity
Environmental fate:		
Persistence/degradation	Presence of polycyclic aromatics and halogenated hydrocarbons	Persistent Degradable
Bioaccumulation	None	Accumulation coefficients
Exposure potential	Related to concentration of constituents in waste	None
Safety:		
Ignitability	RCRA criteria	None
Corrosivity	RCRA criteria	None
Reactivity	RCRA criteria	None

[a] Five hazard classes: +, A, B, C, D (least hazardous).
[b] Four hazard classes: A, B, C, D (least hazardous).

SOURCE: Office of Technology Assessment.

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[34] C. C. Mehlhaff, T. Cook, and J. Knudson, "A Quantitative Approach for Classification of Hazardous Wastes," *Solid Waste Management,* vol. 21, No. 13, 1979, pp. 70-86.

[35] Department of Natural Resources, *Michigan Critical Materials Register* (Detroit, Mich.: State of Michigan, Environmental Protection Bureau, Environmental Services Division, 1980).

[36] JRB Associates Inc., op. cit.

Table 45.—Case Study Wastes

Waste	EPA hazardous waste number	Volume[a] (tons)	Production sites (number)
High volume/high toxicity:			
• Bottom stream from an acetonitrile column in the production of acrylonitrile	K013	337,000	6
High volume/low toxicity:			
• Wastewater treatment sludge from production of titanium dioxide pigment, using chromium bearing ores by chloride process	K074[b]	900,000	
Medium volume/high toxicity:			
• Brine purification muds from the mercury cell process in chlorine production, where separately prepurified brine was not used	K071	42,000 (dry)	27
Low volume/high toxicity:			
• Chlorinated hydrocarbon waste from purification step of diaphragm cell process, using graphite anodes in chlorine production	K073	?	?
• Wastewater treatment sludge from the production of toxaphene	K041	3,750	2
• Distillation bottoms from the production of nitrobenzene by nitration of benzene	K025	500	7
• Ammonia still lime sludge form coking	K060	1,000,000	30[c]
• Spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process, except for precious metal use	F009	22,500 gals	10,000
Low volume/low toxicity:			
• Light and heavy ends from distillation of acetaldehyde in the production of acetic anhydride	Not listed	2,000	4

[a] Annual volumes taken from EPA background documents.
[b] EPA delisted this waste stream.
[c] Process being phased out, by 1982 only 2 companies with a few plants remain.

SOURCE: Office of Technology Assessment.

two to four classes of hazard. In most cases, the hazard class for individual constituents of a particular waste did not vary substantially; it was possible to designate an **average classification** for the waste. The method of averaging was arbitrarily chosen for the purposes of this study. The class designation for the majority of constituents determined the waste average rank. For example, K060 would be assigned to class B in the Washington State system only, since four of its six constituents have that classification. Depending on relative concentration levels for both cyanide and phenol, and the potential for separating these two constituents from the waste before treatment/disposal, the overall classification could be adjusted. For K073, an appropriate classification might be class C because of the distribution of ratings for individual constituents.

An important finding was that **the actual class designation for a particular waste is dependent on the model used,** as illustrated in table 47. It appears that greater discrimination is possible using the Washington State system. A sensitivity analysis would be required to determine which factors contribute to the greater discrimination in this system.

Ranking of landfills using criteria based only on environmental criteria was found to be possible. Though limited, this study shows that even simple classification criteria can distinguish differences in risks posed by different management facilities.

Limitations Encountered

Not surprisingly, the study found significant limitations in data availability, variability, and

Table 46.—Results of Case Study Classification of Wastes

		Washington system		Michigan system	
Waste	Constituent	Average for waste[a]	Constituents	Constituents	Average for waste[a]
K071	Mercury[b]	X[c]	X[c]	A[d]	A[d]
K060	Arsenic[b]	B	B	A	A
	Arsenic trioxide		B	A	
	Arsenic pentoxide		B	A	
	Naphthalene		B	B	
	Cyanide[b]		X	B	
	Phenol		C	B	
F009	Sodium cyanide	B	B	B	A
	Potassium cyanide		B	A	
K013	Acetonitrile	C	C	B	B
	Acrylonitrile		C	B	
	Hydrocyanic acid		A	B	
Heavy and Light Ends	Methyl acetate	D	—[e]	—[e]	B
	Acetone		D	—[e]	
	Ethylidene diacetate		—[e]	D	
	Ethyl acetate		D	B	
K073	Chloroform	C	C	A	B
	Hexachloroethane		B	B	
	Carbon tetrachloride		C	A	
	1,1,2- trichloroethane		C	B	
	1,1,1- trichloroethane		C	B	
	Tetrachloroethylene		C	B	
	1,2- dichloroethylene		D	B	
	1,1- dichloroethylene		C	B	
	1,1,2,2- tetrachloroethane		C	A	
K041	Toxaphene[b]		X	A	
K025	Meta-dinitrobenzene	B	B	B	B
	2,4-dinitrotoluene		C	B	
K074	Chromium[b] (trivalent $CrCl_3$)	D	D	B	B
	Chromium[b] (trivalent Cr_2O_3)		D	B	
	Chromium[b] (hexavalent)		C	B	

[a] Where discrepancies occur among constituents, an arbitrary class designation for the waste was chosen by using the value for the majority of constituents (e.g., K080) or where constituents were evenly divided among classes, the average designation for the waste equaled the highest classification (e.g., F009, rank-order).
[b] May be classified as EP toxic according to either scheme depending on concentration.
[c] X represents most hazardous, D least hazardous.
[d] A represents most hazardous, D least hazardous.
[e] Insufficient data to determine category.

SOURCE: Office of Technology Assessment.

Table 47.—Distribution of Wastes Among Classes

	Hazard classifications[a]				
	X[b]	A	B	C	D
Washington system	K071 K041		K060 F009 K025	K013 K073 K074	HLends
Michigan system		K071 K060 F009 K041	K013 HLends K073 K025 K074		

[a] Left to right represents decreasing hazard levels.
[b] This class included only in the Washington system.
HLends-Heavy, light ends.

SOURCE: Office of Technology Assessment.

interpretation. Data availability is a chronic problem in the design and implementation of environmental regulations, and classification models are no exception. Both of the waste classification models used in this study required more data than was available for some of the waste constituents. Thus, the categorization of many wastes was based on no more than one or two data points. It should be emphasized that this problem is not unique to hazardous waste management, but occurs often in the evaluation of hazards or risks for any purpose.

Data variability also created some difficulties. Even when data were available, they were often not the types required in the models. Currently, there are no standardized methods for correlating test results across species or for different routes of exposure within a species. EPA correlations for cross-species test results compare surface areas of the test animals involved, although these comparisons are not generally accepted by the scientific community. Again, variability in data is a problem common to all areas of scientific inquiry; it arises from differences in the measuring processes and from variabilities in responses of organisms to chemicals. Although this type of variability can never be wholly eliminated, it can be accommodated by using appropriate **ranges** of data values for each critical factor in a classification model.

Because some of the defined categories in the models had very specific criteria, data interpretation became increasingly important. For example, the ranges of values defining a toxicity criterion were, in some instances, narrower than those given in the published data. Thus, it was necessary to represent data rather arbitrarily by a single point in order to assign it to a hazard class. Other problems arose in translating information from published data to the specific requirements of a classification model. For example, the scoring for chronic adverse effects in the rank-order (Michigan) model required information about the reversibility of an effect and concentrations at which reversibility is observed. While published descriptions of chronic effects are sometimes quite detailed, often they do not provide indications of reversibility; to fill in this blank requires expert judgment. Among other problems encountered were the correct interpretation of common labels, such as "potential animal carcinogen." Also, it was difficult to interpret differences in data resulting from variation in the structure of chemicals used in tests (e.g., chemical compounds that are identical except for a particular geometrical relationship in one part of the molecular structure can have substantially different toxicities).

A conclusion to be drawn from the case study is that scientifically defensible and technologically feasible standards and criteria would have to be developed for an acceptable regulatory program based on hazard classification. The criteria must be based on accurate characterization of waste and reliable toxicological information. The rationale for each hazard criterion and its range of values must be stated explicitly. Moreover, in designing a classification system, judgments must be made for such technical issues as:

- **Absolute v. relative toxicity.**—Whether actual values of acute and chronic toxicity should be used as hazard criteria, or whether a scoring system should be devised showing relative toxicity values.
- **Equivalent concentrations v. single constituent concentrations** as the basis for regulation.—Whether to evaluate the hazard of the waste as a whole by combining weighted values of its constituents.
- The need to develop **short- and long-term bioassays for actual waste samples,** rather than for single constituents of the waste—The interaction of constituents may result in a different hazard level from that of the constituents singly.

Problems and Advantages of Classification Systems

Several advantages in using classification systems are apparent. An industrial waste management system that sucessfully matches waste classes with facility classes would provide a consistent level of protection, while avoiding excessive regulation. Highly hazardous waste would be handled at facilities with the highest performance standards; but less hazardous waste would be handled at less cost in facilities designed to less rigorous standards. Other advantages are that government regulations could set priorities for establishing standards and controls on the basis of degrees of hazards for wastes and risks for facilities. In addition, the system could give the public reliable information on the most effective and appropriate ways of handling each class. This last point is particularly important. **At present, the general public tends to consider all industrial waste equally hazardous.** Moreover, many people believe that government is doing very little to protect human health and the environment against these hazards. These perceptions have played a part in the efforts of concerned citizens to halt or delay the development of new facilities. (The section on "Siting" includes a more detailed discussion of these problems.) **Use of a facility classification system in regulation could help to inform the public about the broad range of hazards and risks related to hazardous waste management.** Use of the system certainly will not eliminate public concern, nor perhaps, reduce it. But the result could be to focus public concern more closely on the level of hazard and the various technical possibilities for dealing with these hazards. For example long-term health and environmental consequences of incineration, chemical or biological treatment, and containment alternatives could be drawn to public attention and compared.

Several practical problems, some mentioned in the foregoing discussion, may make it difficult to design a successful system. The difficulties may be summarized as follows:

Mismatches of waste classified by hazard and facilities classified by performance standards might occur. In some instances it may be a mismatch to send only the most hazardous waste to those facilities rated highest in performance. Incineration is an example. Different classes of facilities could represent differences in combustion efficiencies, from 90 to 99 percent. There is no information to suggest that a medium-hazard waste, classed as such based on criteria of toxicity and persistence, presents an equal or lower risk when burned at 95 percent efficiency as compared to a high hazard waste burned at 99 percent efficiency. It is possible that a very hazardous material burns readily and could be incinerated in an industrial boiler, a low-performance facility, thus posing no risk. In contrast, a medium- or low-hazard waste burned in a similar facility may not be readily combusted. If the material is not completely destroyed or if it forms hazardous combustion products, overall greater risk may result than with incineration of the highly hazardous material.

The classification system might also mask critical environmental considerations. A particular waste may have different levels of hazard in different environmental media. For example, a waste constituent may be readily degraded in air but not in soil or sediment. Thus, if incinerated it might pose only a low risk, but for land or ocean disposal a very high risk level could result. A material classed as a medium hazard based on toxicity, genetic impairment, and persistence may be readily mobilized in a landfill. The hazard level results from a **weighting** of several criteria, and therefore, a waste may have medium hazard for cancer, be highly mobile, and perhaps a high hazard for chronic effect such as immunosuppression. The mobility factor, however, is most important for the risk at a water source. If placed in a medium secure landfill and allowed to migrate to water sources, a medium-hazard constituent can cause the same type of adverse effects on the exposed population as a highly hazardous constituent; it may simply require a higher accumulation of the material before the effect is observed.

A related problem is that the **waste characteristics that define a hazard may differ from characteristics that determine the management choice.** Waste classification systems include a diverse range of hazard criteria. The overall hazard rank is a combined weighting of all these criteria. However, from the management perspective **one** specific hazard characteristic often influences the potential risk associated with a particular management option. Such a characteristic could be the high potential for reactivity, which requires a management practice that protects against a short-term hazard. Or if the mobility of an organic waste is the prime concern, management must deal with long-term, cumulative effects. A hazard class could include various waste requiring different technologies. Judgments about the type of waste to be managed in a particular way currently are based on knowledge of the constituents of the waste and limitations of the facility. It is not clear how sophisticated analyses of the hazard potential of a waste before it enters a facility will improve these judgments.

The degree of hazard of a waste may be changed in a management facility. Although each generator can test for hazard characteristics of its particular waste stream, the results may not define adequately the real hazard of constituents released from a management facility. Most facilities are not "mono-" facilities, i.e., they do not accept only one type of waste from one source. Therefore, the hazard class of one type of waste may have little real meaning for the risk potential of a facility. Mixing of several kinds of waste could result in interactions that would change the hazard level of any one or all by either increasing the hazard or decreasing it. If the main concern is the risk to workers at a facility, it may be quite appropriate to focus on the hazards of materials as they enter a facility. But if risk to the general population and the environment is foremost, then the important hazard potential is in the materials that **are released** from a facility.

These difficulties can be resolved. It should be possible to design a system that addresses these problems but does not become overly complex and expensive and thus impractical to implement. OTA's feasibility study indicates that such a system is possible. Because of the advantages classification can offer for regulation of hazardous waste a further study to design an effective, practical system seems justified.

Monitoring

Monitoring provides information essential to reasonable and equitable decisionmaking. The importance of environmental monitoring in pollution-abatement programs is well recognized.[37] [38] The success of pollution control can only be judged by measuring the presence of constituents in all environmental media and comparing these data with measurements taken before the pollution controls were implemented.

Data collected for several purposes (i.e., both to assess environmental quality and to determine compliance with environmental regulations) must be coordinated and available to decisionmakers. Monitoring information is important for decisions on regulatory action by agencies in the executive branch and it is also important for congressional oversight functions. At a 1978 congressional hearing, Representative J. Jeffords (R-Vt.) emphasized this point:[39]

> As a result of . . . lack of an adequate national environmental quality monitoring program, those of us in Congress who are responsible for passing judgment on environmental statutes do not have a solid basis for assessing the success or lack of success of the laws we pass. Moreover, we continually face new environmental crises because we lack the environmental monitoring that might have warned us of emerging problems.

The several different but closely related purposes served by monitoring programs are illustrated in table 48.[40] Adequate data on concentrations of specific compounds, their distribution patterns in the environment, and cause-effect relationships are needed for informed judgments about contamination levels, compliance with regulations, and appropriate performance standards. **Without monitoring data, judgments about the effectiveness of**

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[37] U.S. Congress, House of Representatives, *Environmental Monitoring-II*, hearings before the Subcommittee on the Environment and the Atmosphere of the Committee on Science and Technology, No. 93 (Washington, D.C.: U.S. Government Printing Office, 1978).

[38] National Research Council, *Environmental Monitoring* (Washington, D.C.: National Academy of Science, 1977).

[39] U.S. Congress, House of Representatives, op cit.

[40] Council on Environmental Quality, *Interagency Task Force on Environmental Data and Monitoring* (Washington, D.C.: U.S. Government Printing Office, 1980).

Table 48.—Description of Monitoring Functions

Monitoring function	Description
1. Baseline information	Routine monitoring and collection of constituent information.
2. Standard development	Development of information bases for establishment or revision of constituent standards.
3. Compliance monitoring	Collection of constituent information to verify compliance with regulatory standards set by operations of Federal, State, and local governments and the private sector. Monitor status of environmental control regions.
4. Research and development	Provides information for model development, instrumentation R&D, development testing, or audit of measurement techniques.
5. Public or agency alert	Provides a warning system for agency action and/or public alert.

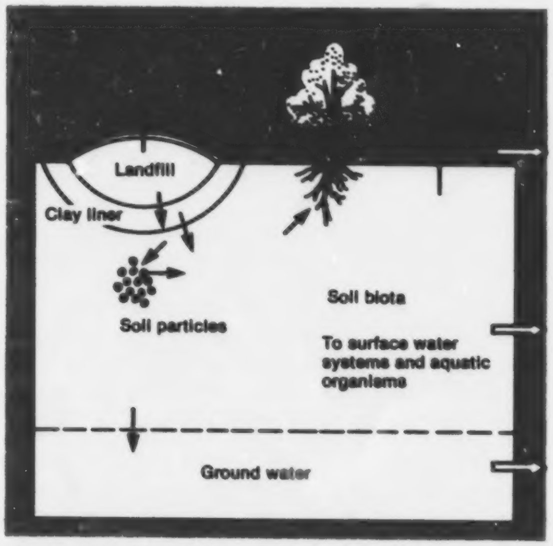
SOURCE: Council on Environmental Quality, 1980.

various waste management options may depend on political interests and individual perceptions.

Monitoring data also provide tangible evidence to a concerned public that human health and the environment are being protected. In the absence of monitoring data, the extent or success of protection offered to human health and environmental stability is only conjecture. **In hazardous waste management, monitoring activities are the only means of verifying that a facility is operating properly.**

Environmental Fate and Design of a Monitoring Program

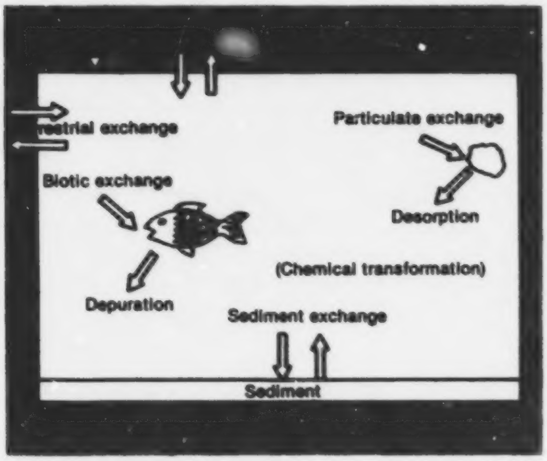
Figure 17.—Potential Transport and Points of Transformation for Land-Disposed Hazardous Waste Contaminants



SOURCE: Modified from G. F. Lee and R. A. Jones - A risk assessment approach for evaluating the environmental significance of chemical contaminants in solid wastes, "Environmental Risk Analysis for Chemicals," R. A. Conway (ed.), 1981.

Several important distribution routes are available to waste constituents once they are released from a waste management facility, as illustrated in figures 17 and 18. The constituents may dissolve in water and percolate through soil into ground water supplies; if well water is drawn for domestic or agricultural use, humans, plants, and animals can be exposed to the contaminated water. Chemicals mobilized through the food chain can present a hazard to humans and higher organisms. (Methylmercury is a well-known example of this.) Chemicals dissolved in runoff water (e.g., materials released through accidental spills or pesticides applied in fields) may enter streams and accumulate in either sediment or aquatic organisms. These materials could be transferred via streams and rivers to sites far from the point of release. Those chemicals with sufficiently high-vapor pressure may evaporate at the point of release, and then may be deposited nearby via rain or snow, or they may be transported long distances depending on prevailing wind currents. Airborne materials can be directly inhaled by organisms. Solid materials (e.g., as powders) stored in surface piles may

Figure 18.—Potential Transformations of Hazardous Constituents in Aquatic Systems



SOURCE: Modified from G. F. Lee and R. A. Jones - A risk assessment approach for evaluating the environmental significance of chemical contaminants in solid wastes, "Environmental Risk Analysis for Chemicals," R. A. Conway (ed.), 1981.

be blown about as dusts and consequently inhaled by humans and animals or deposited on plant surfaces. At any point in the transport of materials, a constituent can be transformed into other compounds that may pose either less or, of particular concern, greater hazards than the parent chemical.

The fate of any substance depends on its interaction with living and nonliving elements of the environment. As illustrated in table 49, each environmental medium (i.e., soil, water, air, and biota) has properties that may influence the way constituents are dispersed, their reactions with environmental components, and their ultimate deposition. Examples of transport and transformation processes that influence environmental fate are presented in table 50. In aquatic systems, for example, organic constituents may be adsorbed on suspended particles and deposited in lake or ocean sediment; thus, the amount of suspended particles and rate of sedimentation affects the availability of these constituents to plants and animals. Similarly in a terrestrial system microorganisms in the soil may degrade a hazardous waste more or less completely depending on the temperature and the availability of nutrients.

Table 49.—Environmental Media and Examples of Properties Influencing the Fate of Waste Constituents

Air
- Temperature
- Wind velocity
- Humidity
- Particulate levels

Soil
- Vegetation cover
- Species composition
- Organic content
- Acid-base level
- Soil composition
- Soil pore size
- Mineral content
- Temperature

Water
- Temperature
- pH
- Suspended solids
- Flow rate
- Sedimentation rate
- Species composition
- Oxygen levels
- Salinity

Biota
- Species tolerance
- Age of individuals
- Metabolic factors
- Mobility
- Species composition

SOURCE: Office of Technology Assessment.

If the quality and quantity of waste constituents released from a facility can be identified, and if general characteristics of the environment to which they are released are known also, the potential for movement of the constituents can be estimated using fugacity equations.[41] Fugacity is defined as the escaping tendency of a substance from a heterogeneous system. Fugacity equations are mathematical models, incorporating data on particular compounds and environmental media, for estimating this tendency. These mobility or fugacity estimates can be used to develop profiles of environmental distribution.

Information needed for such profiles can be obtained through laboratory analysis of the chemical, physical, and molecular characteristics of a compound. Data on physical characteristics provide indications of the relative affinity between a compound and environmental components (e.g., whether it is water soluble, insoluble, or highly volatile). Knowledge of the molecular structure permits estimation of the degradation potential by chemical or biochemical transformations. For example, predictions that a constituent will bind to organic components in soil rather than be transported

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[41] D. Mackay, "Finding Fugacity Feasible," *Environmental Science & Technology*, vol. 13, No. 10, 1979, pp. 1218-1223; and National Research Council, "Chapter 2. Factors Influencing the Fate of Chemicals," *Testing for Effects of Chemicals on Ecosystems* (Washington, D.C.: National Academy Press, 1981).

Table 50.—Examples of Processes Influencing Fate of a Waste Constituent

Physical	Chemical	Biochemical
Transport phenomenon (flow path and rate) (D) • Diffusion (D) • Dispersion (D) • Filtration (D) • Sedimentation (D) • Adsorption—disorption (D)	• Acid-base reactions (D) • Oxidation—reduction (T) • Photolysis (T) • Hydrolysis (T)	• Accumulation—concentration (D) • Mineralization (T) • Cometabolism (T) • Biotic transformations—polymerization, conjugation (T)

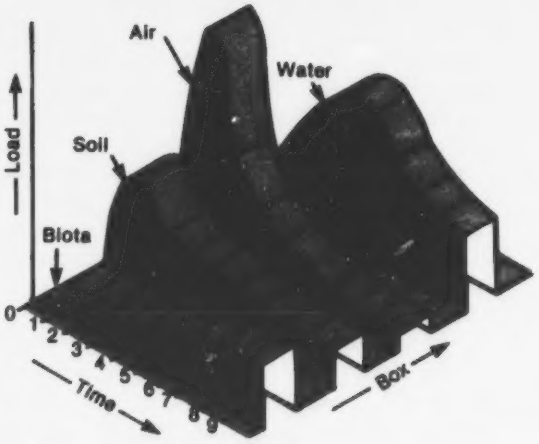
(D) - Distribution/transport.
(T) - Transformation.

SOURCE: Office of Technology Assessment.

to water or air can be made. Those constituents that dissolve readily in water or volatilize rapidly into air also would be identified.

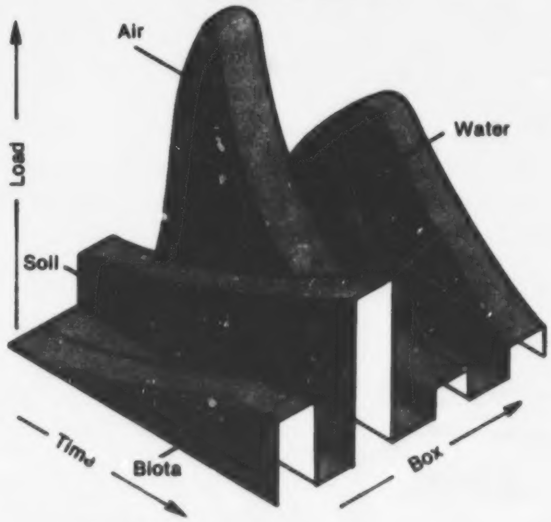
It is unlikely that any waste constituent will be found solely in one environmental medium (i.e., only in soil, or in water); instead it is likely to be distributed across media, albeit unevenly. Figure 19 illustrates a hypothetical profile of environmental distribution.[42] In this example, the chemical is more readily dissolved in water than bound to soil or organic material. Initial concentrations might occur in soil, air, and water. (In a real-world example, the initial distribution of a constituent would depend on the point of release.) As environmental residence time increases, major accumulation occurs in water and biota. In contrast, if chemical analysis indicated strong bonding with organic particles (as illustrated in fig. 20), the profile would differ, with increased concentrations of the constituent occurring in soil or sediment over time. This compound might accumulate in biota at those sites where soil

Figure 19.—A Hypothetical Environmental Fate Profile of a Chemical That Binds Strongly With Lipid Material



SOURCE: Haque, Falco, Cohen, Riordan, 1980.

Figure 20.—Hypothetical Environmental Fate Profile of a Compound That Binds Strongly With Organic Material



SOURCE: Office of Technology Assessment.

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[42] R. Haque, J. Falco, S. Cohen, and C. Riordan, "Role of Transport and Fate Studies in the Exposure Assessment and Screening of Toxic Chemicals," *Dynamics, Exposure and Hazard Assessment of Toxic Chemicals* (Ann Arbor, Mich.: Ann Arbor Science Publisher, Inc., 1980).

or sediment-dwelling organisms are present. The final concentrations in air and water would probably be minimal.

Knowledge of this potential distribution is quite useful in designing a monitoring program for a particular site. For a profile such as figure 19, monitoring efforts initially would concentrate on sampling all media. Over time, greater efforts could be devoted to analysis of water and biotic samples with a reduced effort in soil and air sampling. Spot checks might be necessary to verify that there is not continual release of constituents from a facility. In the second figure, sampling of soil would have highest priority, with lesser and decreasing emphasis on water and air analyses. Thus, the ability to predict environmental fate of waste constituents using fugacity equations can promote development of cost-effective programs by indicating where sampling efforts may best be concentrated.

Monitoring Activities: Types and Strategies

Monitoring includes a variety of activities. It can refer to observation of the operation of an industrial process (e.g., the chemical treatment of a waste), the inspection of the integrity of a facility, or the effects of an industrial waste constituent on organisms. Five types of monitoring—visual, process, source, ambient, and effects—can be used alone or in combination with two different strategies—surveillance and assessment.

Five Types of Monitoring

Most types of monitoring that can be applied to waste management practices (i.e., all but effects monitoring) focus on identifying the occurrence and extent of releases of waste constituents to the environment. This monitoring may be part of an information feedback system for a facility operation; or it can provide data needed for developing standards and to identify research needs (see table 48). Ambient monitoring also is used to establish baseline data. Ambient and effects monitoring provide data for setting research priorities and for measuring quality of public health and the environment. Effects monitoring is aimed at determining cause-effect relationships between hazardous constituents and adverse effects observed in humans or other organisms.

1. **Visual monitoring** is the simplest and least costly method of identifying releases of constituents from a waste management facility. Routine procedures—checking for container leaks and for proper storage of materials as well as containers—are useful in monitoring hazards associated with ignitable, corrosive, and reactive materials. Visual inspections immediately identify the potential for fugitive emissions, accidental spills, and generally unsafe conditions at a facility site.
2. The purpose of **process monitoring** is designed to determine that a process (e.g., waste recovery, incineration, or biological treatment) is operating in accordance with specific standards. Factors that control a process (e.g., temperature and flow rate in an incinerator) are checked for variations from an established level. Process monitoring is based on the principle that chemical, physical, and biological reactions are predictable, and that conditions under which they occur can be controlled. This type of monitoring therefore consists primarily of surveying normal engineering information provided on meters and gages. In many large industrial facilities, continuous monitoring is performed with the aid of a computerized system. If a specified condition (e.g., temperature) exceeds certain preestablished levels, the system automatically shuts down the process and sounds an alarm. Process monitoring can be extremely effective. Recordkeeping can be done on a routine basis and the skill level required is not high; the technician is required to read gages or computer printouts. Costs for this type of monitoring are primarily for equipment and technician time. The challenge is to channel the flow of this information from the plant operations level to the risk management level.
3. **Source monitoring** verifies that the flow of material from a facility to air, soil, or

water does not contain harmful or unexpected constituents. In general, indicator compounds and conditions, rather than specific chemicals, are monitored continuously with such measurements as pH, temperature, total organic content, specific metals, and oxygen levels (for water sampling). If significant variations in these measurements are detected, more comprehensive analytical tests can be conducted to identify the specific problem. The presence of unexpected constituents or increased concentrations in an industrial effluent (e.g., increased levels of total organics) would signal that the facility may not be operating correctly.

This type of monitoring activity is a second-stage alert system for an industrial operation, with visual inspections and process monitoring the first stage. With appropriate indicators, source monitoring can be very effective. EPA has required it for monitoring compliance of industries with certain environmental regulations (e.g., regulations promulgated under the Clean Air and Clean Water Acts.) Automation and remote control of sampling and analysis have made second-level monitoring activities relatively simple, as long as outflow constituents can be identified for analysis. More highly skilled personnel are needed than in process monitoring; special training is required in sampling and analytical methodologies.

4. **Ambient monitoring** is the third level of activity. It can provide baseline data for a specific area, and also provide data after the release of hazardous constituents into the environment for comparison. Ambient monitoring is much more complex than the first two levels, requiring carefully controlled sampling and analysis of a diverse set of materials (e.g., soil, water, air, plant and animal tissue). The environmental components are themselves variable, which can complicate interpretation of results. With the availability of complex analytical equipment (e.g., the gas chromatograph-mass spectrophotometer), the identity and concentrations of many different constituents can be detected at very low levels (parts per billion).

   The cost of ambient monitoring is a function of the degree of knowledge desired regarding the fate of constituents. After a release of constituents into the environment, the precise form, concentrations, and locations of constituents becomes harder to determine with time. A greater number of samples is required to assess the full extent of contamination over time. The level of detail and precision desired also affect costs. Some relatively simple analytical techniques can detect classes of constituents by measurement of chemical and physical processes. To determine more precisely the qualitative identity of a single constituent, or the extent of its distribution, requires more complex, costly equipment. The skills required for these types of testing requires several years of training in technical fields and extensive training on specific analytical equipment.

5. **Effects monitoring** entails observing humans and other organisms for adverse, or beneficial, effects resulting from the presence of, or exposure to, constituents above naturally occurring levels. It is expensive and time-consuming, since it often takes several months or years for an effect to appear (e.g., as illness or death in the human population, or decreases in animal population sizes). As discussed previously in this chapter, it is very difficult to determine direct relationships between the presence of a contaminant and particular adverse effects for human health. Because cause-effect relationships have not been established for most waste constituents, data from this type of monitoring can be used to set research priorities and to evaluate environmental quality.

Of the five types of monitoring discussed above, **ambient monitoring has the greatest potential to serve as evidence that risks associated with hazardous waste management are kept to acceptable levels.** Visual inspections along with process and source monitoring, if effectively carried out, can reduce the amount of ambient monitoring needed; however, they cannot serve as substitutes. Only by taking representative samples from potentially affected environmental media and analyzing them for a broad spectrum of indicators is it possible to control risks reliably and realistically. Increased use of fugacity predictions can contribute to more cost-effective ambient monitoring programs. Greater use of multimedia monitoring programs are needed.

Public health can best be protected by preventing hazardous releases and minimizing contamination of the environment. Should releases occur, ambient monitoring of the environment can produce early warning of threats to public health. The environment can serve as a protective barrier. If contamination of the air, water, and land is detected early (before widespread contamination and actual damages), corrective action can be taken, and human exposure reduced. For example, a persistent hazardous compound might be detected in soil surrounding a waste management facility, but nowhere else. If it can be removed, or in some way immobilized before reaching water or critical points in food chains, then exposure to humans and other organisms is prevented. Ambient monitoring, therefore, should be given a prominent role in monitoring programs.

Two Monitoring Strategies

Monitoring programs serve two different types of strategies: surveillance or assessment. **Surveillance monitoring** usually is used to verify compliance with regulatory standards; it provides only limited information on trends or changes in broad categories of monitoring indicators. It could include visual, process, source, and ambient monitoring activities. Sampling efforts for surveillance strategies should occur close to the source of constituents for three reasons:

1. to reduce the number of environmental processes that can interact with and thus change the constituents of concern,
2. to restrict the number of sites that need to be monitored, and
3. to allow early warning of contamination problems.

Surveillance methodologies usually incorporate indicators for broad categories of contamination. The resulting lack of detail, however, limits the usefulness of these data. Surveillance monitoring indicates changes in broad categories of constituents or environmental conditions, but does not provide detailed information on specific constituents or potential impacts. Surveillance strategies are usually focused on specific requirements for environmental regulations, e.g., monitoring requirements in RCRA regulations.

Assessment monitoring serves two purposes: to show the extent of contamination from release of hazardous constituents and to indicate cause-effect relationships. Assessment monitoring generally involves detailed ambient and effects monitoring. Sampling techniques and analytical procedures are more detailed for assessment than in surveillance monitoring. A wide range of sample types is collected for analysis and very carefully designed protocols are used. Reference standards and quality control procedures are essential to assure that the data are valid and can be statistically verified.

Major Technical Issues in Monitoring

Several problems affect any monitoring effort. If valid conclusions are to be drawn from an analysis of data, the analyst must recognize and resolve problems of sampling frequency and preparation, data compatibility, and limitations of analytical methodology.

Sampling

Sampling is one of the most critical and most inexact steps in the monitoring process. The objective in sample collection is to obtain a number of samples that is both manageable and representative of the system being monitored. The choice of medium (air, water, soil, and biota) is a critical factor. Despite care in the selection of samples, however, the inherent variability of ecosystems, and the variations in interactions of hazardous waste constituents and elements within a system, result in a minimal level of uncertainty that can never be overcome.

As discussed previously, fugacity profiles can determine major areas of concern and thus simplify choices of sampling air, water, or soil. Obtaining representative samples of biota is complicated. Different species have different reactions to waste constituents. Furthermore, the site of accumulation in plant and animal tissue varies. For example, certain crops such as beets, lettuce, and tomatoes accumulate toxic metals more readily than do beans or cabbage; also, the foliage of such plants will contain higher concentrations than do the root structures.[43]

Location of the sampling effort is very important. Ecosystems are dynamic. For example, conditions along a large river may vary considerably. Changes in temperature, even of only a few degrees—depending on the amount of shade along river banks—can affect the river ecosystem and the impacts of constituents. Changes in rate of flow may be observed and may have similar effects. Thus, to properly monitor a river, factors such as distance to shore, water depth and flow, and type of constituents of interest will influence the optimal sampling location. The desired frequency of sampling depends on temporal variations. Environmental conditions fluctuate with the season, month, day, and even hour. Random weather events, such as storms, can affect the quality and representative nature of samples.

Sampling techniques must also consider the type of ecosystem being monitored. Because there is less mixing in ground water aquifers than in surface waters, a nonuniform distribution of constituents can be expected in the former, thus requiring vertical sampling over several horizontal locations to obtain a truly representative picture. Surface water sampling may, on the other hand, require only horizontal sampling if the water body is shallow.[44]

Data Comparisons

An effective monitoring program must have baseline or control data available against which comparisons can be made. At present, there are insufficient data to establish baseline values for hazardous waste constituents in the environment. Therefore, it is difficult, but not impossible, to determine trends in human-caused releases vis-a-vis contributions of these constituents from natural sources. In the absence of preexisting baseline information, the preferred course is to monitor at the site of concern **before** and **after** new sources of environmental contamination are expected or new facilities are established, thus establishing baseline data for the new site. The alternative is to obtain control data in a nonaffected area (without industrial development) that has environmental characteristics similar to the affected site. Monitoring programs for existing facilities must rely on this method.

Both approaches require the use of comparable standardized sampling and analytical procedures. If noncomparable protocols are used, observed difference in the data could be interpreted as resulting from different sampling and measurement methods rather than from changes in environmental concentration of hazardous waste constituents.

Unfortunately, standardized protocols are usually unavailable.[45] The few that have been developed are not often uniformily applied. Even though a laboratory may rely on standardized methodology, modifications can be expected based on new research results or personal preferences of the staff.[46] Analytical variations can arise even when different persons perform the same procedures using the same equipment. Interlaboratory variation caused by slightly different procedures and different equipment create even larger and more complex problems for data comparisons.

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[43] E. Epstein and R. L. Chaney, "Land Disposal of Toxic Substances and Water Related Problems," *Journal of Water Pollution Control Fed.*, vol. 50, No. 8, 1978, pp. 2037-2043.

[44] U.S. Environmental Protection Agency, "Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities," SW-611, 1980.

[45] National Research Council, *Environmental Monitoring* (Washington, D.C.: National Academy of Science, 1977).

[46] U.S. Environmental Protection Agency, "Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities," SW-611, 1980.

A review of Federal monitoring programs by the Council on Environmental Quality (CEQ) indicated that quality assurance efforts within **a monitoring program were inadequate.**[47] Of particular concern was the lack of quality control regarding siting criteria, field methodology, sample preservation, and sample storage. The report states:

> Although various quality assurance programs have been adopted by Federal agencies with monitoring programs, many of these programs lack basic policy endorsement by agency management, suffer from insufficient commitment of resources, do not provide specific guidance to field monitoring organizations, and are not coordinated when more then one agency is involved. Until these deficiencies are corrected, a significant number of agency decisions and policies will be based on data of questionable and/or unknown accuracy.

An attempt to develop national quality assurance programs for hazardous waste analyses is currently underway in the Environmental Monitoring Support Laboratories of EPA.[48] The aim of this new program is to develop standardized analytical methodology and to provide reference standards for analytical results. The problem of quality assurance, however, is far from being resolved through this effort and continued work is needed. Two critical areas require further development:

- standardized methods for sample collection, analysis, storage, reporting, and field verification of results, and
- certification of laboratories and development of suitable reference standards to increase the comparability of interlaboratory data.

It should be emphasized that the **purpose of quality assurance programs is to provide the user of the data with an estimate of its accuracy or uncertainty.**

Degrees of accuracy, precision, and uncertainty of data are not always acknowledged; nor are acceptable levels of precision and uncertainty always identified for the particular uses of the data (e.g., for policy or regulatory compliance and enforcement). Not all programs or uses of monitoring data require the same level of precision; this varies according to the purpose of a particular program. For example, the precision required for surveillance programs may be less than that required for assessment efforts. Two questions might be asked to determine the appropriate level of precision:[49]

1. How will the data be used?
2. What are the consequences of obtaining imprecise data?

For data being placed in national data banks some indication of the data's precision is especially important. If data leave a laboratory without proper caveats, these data may be misused. It may be necessary to require this information for Federal data banks, as data are incorporated into the system.

Limitations of Analytical Methodology

Analytical methodology used for samples from one environmental medium cannot be easily transferred to another medium. For example, considerable R&D has been directed toward developing analytical techniques for water quality analysis. Before these techniques can be used for hazardous waste surveillance or assessment efforts, however, they must be modified to suit the specific conditions and materials of concern in hazardous waste management. Methods for air, soil, and biota can be decidedly different in sampling techniques, handling, preservation, and analysis because of the quality and quantity of sample that may be required in each situation. The development of proper methodologies and protocols is not an impossible task, but it will require both added funds and trained personnel—both currently in short supply in hazardous waste management.

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[47] Council on Environmental Quality, *Interagency Task Force on Environmental Data and Monitoring* (Washington, D.C.: U.S. Government Printing Office, 1980).

[48] S. Miller, "Quality Assurance, Analytical Methods, and Hazardous Wastes," *Environmental Science and Technology*, vol. 16, No. 6, 1982, pp. 332A-336.

[49] D. Friedman, "Validity and Reliability of Sampling Data," unpublished paper (Washington, D.C.: U.S. Environmental Protection Agency, Office of Solid Waste, Waste Analysis Program, 1981).

Some attention should also be given to defining general test indicators for the diverse range of hazardous constituents. For example, RCRA monitoring requirements for land disposal require consideration of more than 387 compounds that are currently considered as hazardous by EPA (discussed in ch. 7). Current capabilities for the detection of a majority of these compounds with state-of-the-art analyses is questionable. In some cases, appropriate analytical protocols are not available for waste constituent analysis. In others, the detection limits of analysis may be higher than concentration of constituents in waste. Depending on the type and sophistication of the analytical equipment, it is possible that a constituent could be present but not detected by laboratory analysis.

The use of indicator test compounds (i.e., one or two compounds selected to represent the presence or absence of a class of compounds) has been suggested. While such methods provide economic advantages, continued environmental contamination may occur if the hazardous compounds in any waste do not behave environmentally in the same manner as the indicator compounds. Also, because of the nature of many of these compounds (e.g., the complex organics) equally hazardous degradation products may result from environmental transformations. Only limited information concerning these transformations currently is available.

Monitoring efforts developed in response to the Clean Air and Clean Water Acts have emphasized chemical analyses, and RCRA requirements followed these precedents. Because of the extensive number of hazardous constituents that may require analysis even at the level of surveillance efforts, reliance on chemical analyses alone can become very expensive. Therefore, it may be prudent to investigate the use of biological indicators. There has been research on advantages and limitations of biological monitoring programs, but specific applications for hazardous waste management must be explored. (See reviews of biological monitoring applications.[50])

Institutional Approaches to Technical Issues

Scientists, both in the public and private sectors, recognize the importance of proper sampling techniques, data compatibility, and limitations in the methodology. Yet, no major governmental policy has been directed towards developing solutions. These problems are not unique to hazardous waste management. They are relevant to all regulations intended to reduce undesirable levels of contaminants in our environment. **Effective protection of human health and the environment requires concerted efforts to develop adequate monitoring programs.** Three activities could help to correct the current deficiencies.

First, it may be **prudent to centralize monitoring activities** responsible to resolve the technical issues addressed here by drawing on the help of government and nongovernment laboratories and personnel. EPA's Environmental Monitoring Laboratory, for example, might be charged with developing standardized sampling protocols, while the National Bureau of Standards would continue its work of developing reference test standards. The American Society of Testing Material (ASTM) could develop methodological protocols for analytical work, and the National Science Foundation (NSF) and universities could be called on to help establish compatible and coordinated baseline data.

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[50] J. Cairns, Jr., et al., "Suitability of Some Fresh Water and Marine Fishes for Use With a Minicomputer Interfaced Biological Monitoring System," *Water Resources Bulletin*, vol. 16, No. 3, 1980, pp. 421-427; J. Cairns, Jr. and D. Gruber, "A Comparison of Methods of Instrumentation of Biological Early Warning Systems," *Water Resources Bulletin*, vol. 16, No. 2, 1980, pp. 261-266; J. Cairns, Jr., "Biological Monitoring—Concept and Scope," *Environmental Biomonitoring, Assessment, Prediction, and Management—Certain Case Studies and Related Quantitive Issues* (Fairland, Md.: International Cooperative Publishing House, 1979), pp. 3-20; D. Gruber and J. Cairns, Jr., "Industrial Effluent Monitoring Incorporated Recent Automated Fish Biomonitoring System," *Water, Air, Soil Pollution*, vol. 15, 1981, pp. 471-481; J. M. Thomas, D. H. McKenzie, and L. L. Eberhardt, "Some Limitations of Biological Monitoring," *Environment International*, vol. 5, 1981, pp. 3-10; and W. H. Van Der Schalile, et al., "Fish Bioassay Monitoring of Waste Effluents," *Environmental Management*, vol. 3, No. 3, 1979, pp. 217-235.

In 1978, the U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Environment and the Atmosphere, held hearings on a proposal to provide for a demonstration of a coordinated management system for environmental monitoring efforts.[51] The testimonies presented at subcommittee hearings strongly supported such an effort, indicating that it was both possible and desperately needed. All the witnesses agreed that cost-effective programs can be developed.

Because of the multidisciplinary and multimedia approach necessary to meet environmental monitoring needs, a second activity might be the **establishment of a pilot project** (as suggested by testimonies at the hearing). Its purpose would be to identify the most effective strategy and to develop standard protocols for sampling, analytical procedures, and data storage. Such an effort is essential when addressing monitoring needs for hazardous waste management. Standardized monitoring practices are imperative for identifying contamination and verifying concentration levels. Because of the possibility of widespread environmental contamination with only limited resources for pursuing monitoring activities, carefully designed and cost-effective programs are the only means of providing information to verify that the public and environment are being protected under RCRA.

Monitoring programs have been established for the seven major environmental statutes and data collection activities are extensive, but lack coordination. The third activity for institutional improvements would be **coordination of environmental monitoring programs.** During the late 1970's, the executive branch expressed concern about deficiencies in national monitoring programs, and an interagency task force was formed to study the situation. The report of this task force was released in 1980 by CEQ.[52] It concluded that agencies generally develop a monitoring program to meet a specific legislative need and do not consider how the data might be used by both the public and private sectors. The report concluded that:

> This absence and/or lack of widespread user awareness of the existence of the various systems is causing the development of new systems which overlap existing systems. In short, there is a lack of government-wide efforts to ensure that both existing and new Federal systems and data standards are properly coordinated to minimize duplication and to ensure that such systems provoke the broadest possible services to users in the most cost-effective manner.

There has been some effort to coordinate certain programs such as water monitoring data and climate and ocean monitoring programs. But the extent of this coordination is limited.

Many current monitoring efforts are designed for a single environmental medium. For example, water data are collected for the Clean Water Act, air data for the Clean Air Act, and soil data are collected by the U.S. Geological Survey (USGS). Because of widely differing methods used for sample collection, analysis, and storage, it is very difficult to assess exposure and contamination across media. **Such an effort is particularly needed in waste management because of the multimedia nature of risks associated with hazardous waste.**

As illustrated in figure 21, the scope of environmental monitoring efforts within the Federal Government is wide ranging. Each of these programs could augment a hazardous waste management system, particularly in a national scheme aimed at risk management. If properly selected, focused, analyzed, and integrated, the data could provide a scientific basis for regulatory action on waste management. Without a nationally coordinated data-gathering and storage effort, and without proper quality assurance guidelines, the current data bases will

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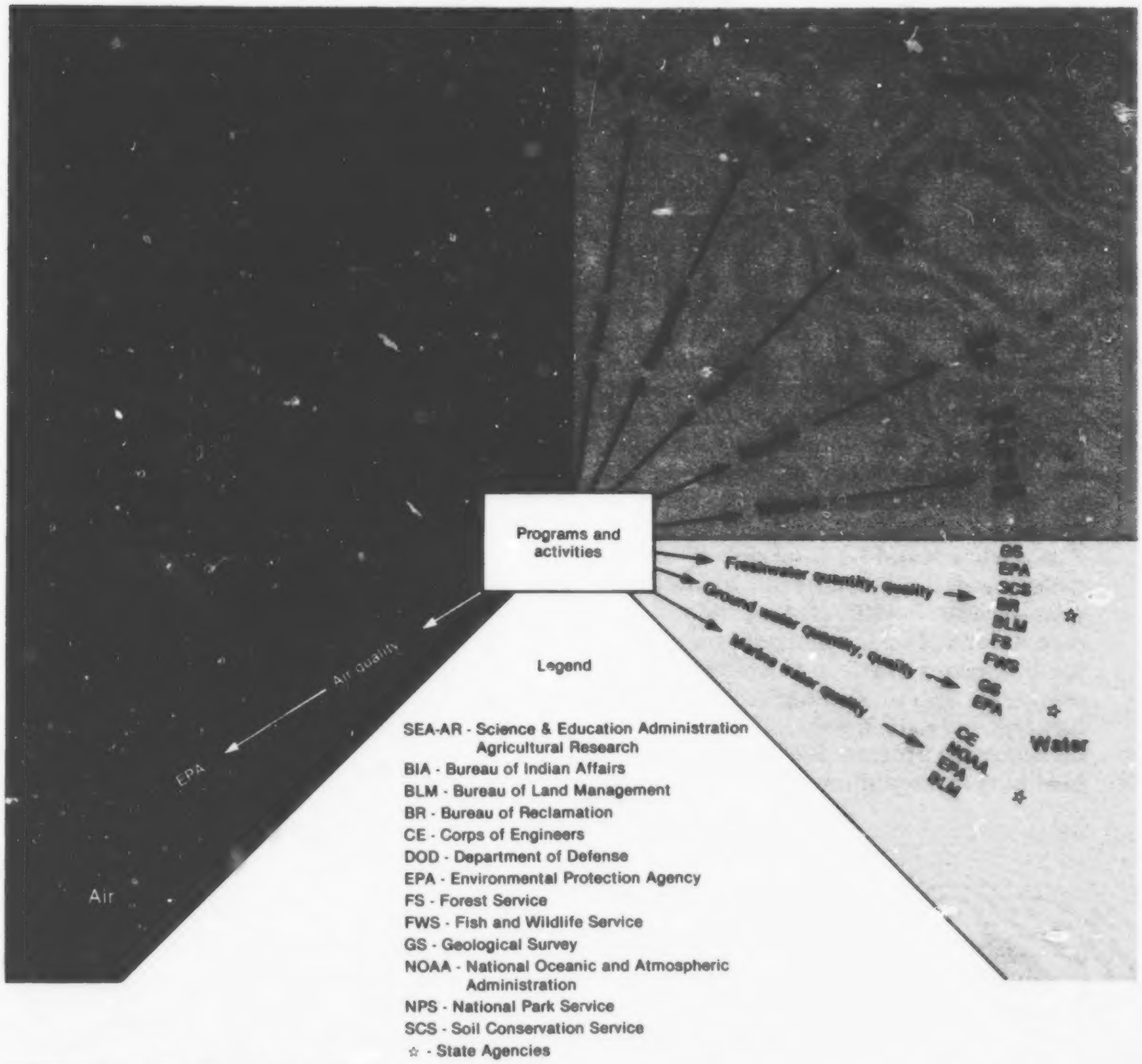
[51] U.S. Congress, House of Representatives, *Environmental Monitoring—II*, hearings before the Subcommittee on the Environment and the Atmosphere, Committee on Science and Technology, No. 93 (Washington, D.C.: U.S. Government Printing Office, 1978).

[52] Council on Environmental Quality, op. cit.

Figure 21.—Ecological and Living Resource Information and Data Gathering Programs Within the Federal Government


Programs and activities
Air quality
EPA
Air
Freshwater quantity, quality
GS
EPA
SCS
BR
BLM
FS
FWS
☆
Ground water quantity, quality
GS
EPA
☆
Marine water quality
CE
NOAA
EPA
BLM
☆
Water
Legend
SEA-AR - Science & Education Administration Agricultural Research
BIA - Bureau of Indian Affairs
BLM - Bureau of Land Management
BR - Bureau of Reclamation
CE - Corps of Engineers
DOD - Department of Defense
EPA - Environmental Protection Agency
FS - Forest Service
FWS - Fish and Wildlife Service
GS - Geological Survey
NOAA - National Oceanic and Atmospheric Administration
NPS - National Park Service
SCS - Soil Conservation Service
☆ - State Agencies

SOURCE: Council on Environmental Quality, 1980.

remain inadequate for broad applications of environmental assessment, including the management of hazardous waste.

The following recommendations made by the Interagency Task Force have direct application to the monitoring needs and problems for hazardous waste management. No action has been taken on these recommendations.

1. **Establish a national program to provide a governmentwide scientific focal point for environmental information and analysis related to environmental assessment.** A national program that coordinates data collection, assesses its quality, and encourages its distribution would help eliminate problems of expensive, overlapping

Federal and State hazardous waste monitoring programs, inadequate environmental assessments, delays in formulation of regulations, and poor intergovernmental conditions.

2. **The existing interagency coordination of water data collection should be strengthened.** The current emphasis on water data related to hazardous waste management is for ground water only; surface water monitoring is also needed. By strengthening the existing data bases (e.g., EPA's STORET) and coordinating data collection efforts, duplication of monitoring activities by Federal and State Governments, universities, and industry could be avoided. At a time when staff and financial resources are limited for hazardous waste management, a coordinated monitoring program has much to offer in the way of reduced costs.
3. **Establish a standing interagency group to deal with the coordination of environmental and health effects data.** This recommendation is especially important for hazardous waste management. Currently, the extent of integration of these two types of data is very limited, but, if a management program is to protect human health, this integration is necessary.
4. **Quality assurance should be a major part of any monitoring effort and should receive substantive consideration for design and funding.** Without the existence of data standards and definitions, it will be very difficult to enforce the RCRA regulations uniformly. Industry has the right to be assured that compliance requirements are uniform nationwide and that a decision of noncompliance truly represents noncompliance rather than differences generated by monitoring methodology.
5. **Implement an integrated Federal environmental data system that can be used in making broad policy decisions.** Such a data base would provide the means for multimedia analysis related to hazardous waste contamination. Such analyses are currently not possible.
6. **NSF should initiate a program to support projects that are aimed at long-term data collection at a series of locations. These should represent a cross-section of major ecosystems in the United States.** Such a monitoring effort would provide baseline measurements to which hazardous waste monitoring data could be compared.

Siting

A paradox exists between the public desire for safe hazardous waste management and public rejection of sites for specific hazardous waste facilities. The reasons for the dilemma are easily identified; solutions are more elusive. The reasons for the almost universal opposition to hazardous waste facilities in one's own neighborhood include:

- fear of health or safety effects,
- fear of economic losses,
- uncertainty of industry's ability to prevent adverse consequences, and
- lack of confidence in government.

The overwhelming reason for public opposition is a fear for personal health and safety. This fear is not based on objective evidence of cause-effect relationships between exposure to hazardous waste and adverse health effects. Rather, it comes from perception of uncertainties surrounding these cause-effect relationships. As discussed previously in this chapter, scientific data suggest a **potential** for long-term chronic health effects from exposure to hazardous waste. Most people do not wish to take the risk, uncertain as it may be. Thus, the public opposes siting and permitting of facilities near residences and workplaces.

The economic concern is twofold: the fear of a decline in property values and knowledge that compensation for any damage that may occur to property or health is limited or nonexistent. Expeditious compensation for personal injury directly related to the operation of a waste management facility is by no means assured. In fact, the barriers to recovering some sort of damages through litigation are substantial. Lawsuits are long and costly, and it may be exceedingly hard to prove either cause-effect relationships or negligence by the facility owner. Under CERCLA, the owner of the facility is liable for government costs of cleanup, but not for compensation of personal or property losses to third parties.

Because of **past** problems with the waste management industry, the public appears reluctant to take a chance on new technologies. This is particularly true for the siting of land disposal facilities. Uncertainty about the capability to prevent adverse consequences extends to other management facilities as well (e.g., incinerators). Concerns that the personnel at waste management facilities are inadequately trained and that good "housekeeping" practices will not be followed voluntarily, contribute to public fears.

Lack of confidence in governments stems from several causes. First, many citizens are concerned that Federal and State regulatory programs are not stringent enough. (These programs are discussed in ch. 7.) There is concern that government monitoring and enforcement efforts are inadequate. Government responses to citizen complaints have contributed to this concern. For example, a waste facility in Wilsonville, Ill., was approved by the State several years ago, despite strong public opposition. Opposition continued and the site was recently closed by an order from the State Supreme Court. The company has been ordered to exhume all materials, but unfortunately, toxic organic solvents have already leaked from the disposal site. At another site, in Sheffield, Ill., organic solvents have passed through a barrier wall within a few years, although the State regulatory agency claimed that the barrier would prevent migration for 500 years.

Public mistrust of regulatory agencies is aggravated by government actions following the discovery of hazardous waste pollution, which often seem too late, ineffective, or unresponsive to concerns of citizens. For example, homeowners near a large landfill in southern California (the BKK landfill in West Covina, Calif.) have complained for years about the nuisance and danger to drinking water supplies posed by waste disposal at that site. The State response was less than rapid.[53] Another example is the actions of EPA and Colorado in granting interim status to the Lowry Landfill near Denver, despite citizen legal action to close the landfill based on the charge that toxic waste leaking from it were contaminating Denver's drinking water supply.[54]

A final, though less obvious, reason for public skepticism about the ability of government to deal effectively with hazardous waste concerns is the lack of a real commitment by government to reduce the production and toxicity of hazardous waste. Many hazardous waste management programs place great emphasis on waste **disposal,** rather than on other management options. The public's reluctance to accept new land disposal facilities may well be linked to the limited attempts by government to promote preferable treatment alternatives and waste reduction.

Approaches to Addressing Public Concern

There are two approaches to answering public concern over siting of particular facilities. The "technical" approach is based on requirements that sites meet protective siting standards, and the provision of enough technical information to increase public understanding of proposed facilities. The "nontechnical" approach includes assurance of public participation in siting decisions, compensation for victims of damage, a clear commitment by government to enforcement of regulation, and possibly, incentives for communities to accept proposed facilities.

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[53] State of California, Office of Planning and Research, "Improvements in Siting Hazardous Waste Facilities, Recommendations of the Department of Health Services Advisory Committee," Sacramento, Calif., June 1982.

[54] C. Maclennan, testimony before the U.S. House of Representatives Subcommittee on Commerce, Transportation, and Tourism, Committee on Energy and Commerce, Apr. 21, 1982.

That public opposition to hazardous waste facilities will be wholly eliminated is unlikely. But if public concerns are seriously addressed, some sites may become acceptable. The most important ways to do this are to involve the public early in the process (possibly at the point of establishing siting criteria) and to make sure that all relevant technical information is readily available to the public. Already, the importance of public access to information during the siting process is generally accepted. Procedures are established for making information available, and if trade secrets must be withheld, the reasons and the conditions for secrecy are generally agreed on in advance. Public involvement could be further encouraged. Especially important is education in hazardous waste management, participation in the siting decision, and continuing "watchdog" review to ensure government and industry accountability after the site is approved and the facility is in operation.

Commitment to public participation seems to have been the key to acceptance of several proposed hazardous waste facilities. Many State governments have recently established siting procedures that are especially tailored to hazardous waste issues and that include public participation. For example:

- Minnesota is one of 10 States with a siting board which is solely responsible for locating and acquiring suitable sites for hazardous waste disposal facilities within the State. Citizens unaffiliated with government or the hazardous waste industry are on Minnesota's Waste Management Board, and the State's siting process offers frequent opportunities for public participation.
- California is one of several States where local government approval is a prerequisite for the siting of a hazardous waste facility.
- Massachusetts has a hazardous waste siting process that stresses negotiations between the community and the hazardous waste facility developer and/or binding arbitration.[58] Because the system is still in the early stages of development, its success has not yet been demonstrated.
- New York has a streamlined State permit process leading to a Certificate of Environmental Safety and Necessity for hazardous waste facilities. These permits are issued by the State and supersede, or preempt, local permit requirements. At least six States have similar programs.

Different States take widely different approaches to siting. No one system is demonstrably superior. Success in siting appears to correlate more with public understanding of the process and public involvement in decisionmaking, than to the particular type of siting process.

Technical Methods

One vehicle for improving public involvement in siting is the adoption of a comprehensive hazardous waste plan, jointly developed by industry, government, and the public. The purpose of the plan would be to provide accessible technical material. It would include accurate and detailed information on hazardous waste quantities and types, sources of waste, environmental conditions of the proposed site, and potential adverse impacts on health and the environment of the waste or its constituents. **Most of the opposition to siting hazardous waste facilities has to do with sites for land disposal. In these cases, opposition may be less if it can be demonstrated convincingly that all options for waste management have been pursued (e.g., that waste reduction, recycling, and treatment facilities have been evaluated prior to the siting application). This close consideration of alternatives should be one of the requirements in a comprehensive waste management plan.**

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[58] *The Siting Book, A Handbook for Siting Hazardous Waste Facilities in Massachusetts*, Department of Environmental Management, Bureau of Solid Waste Disposal, October 1982.

Another way of responding to public concerns is to establish technical siting criteria. The criteria might ban certain kinds of facilities from specified areas (e.g., within a 100-year flood plain or above a ground water recharge area). If high-risk sites are eliminated by the technical criteria, facilities may be sited in areas more acceptable to the public.

Some States are considering the use of criteria and the siting process to identify a "bank" of suitable facility sites. Some analysts have suggested that the potential risks from a new facility should be compared and related to risks posed by other land uses in the community, such as existing manufacturing plants that discharge pollutants, airports, fuel storage tank farms with the potential for explosion, etc. The comparison might shed a more favorable light on a waste facility siting proposal, or it may help to identify an area in the community where the additional risks posed by a new hazardous waste facility are compatible with other land uses.

An important part of openness in siting programs is the provision of information on the roles of the major regulatory agencies involved and on the companies in the waste disposal business. Documents provided might include applicable regulations, descriptions of current and past enforcement efforts, reports on State and Federal hazardous waste programs, annual reports of leading companies in the industry, and publications from industry trade organizations describing typical waste management policies and practices.

Economic and Institutional Mechanisms

Several nontechnical measures can be taken to address public concerns about hazardous waste siting in the communities. For example, information can be provided on the economic advantages to the community. A community may benefit from higher revenues, through a tax on the gross receipts of a facility, property tax, or treatment disposal fees.

Another potential economic benefit could be new industrial growth attracted by the availability of waste management capacity. This might increase regional employment. Similarly, a waste facility could help existing local industry by offering reasonably priced and reliable waste management services. A proposed facility that presents clear-cut benefits to local existing industry is more apt to win favor than one that serves a wider area. This was demonstrated recently in New Jersey. A proposal to construct an onsite landfill for hazardous waste generated by a local chemical company (and employer) was approved, while a similar proposal for an offsite chemical waste landfill serving a large geographical area was vociferously opposed and defeated.

A problem with economic benefits, however, is that the risks and the benefits do not always coincide. The community or neighborhood nearest the waste facility may be running the greatest risks, while the benefits are spread out over a much larger community, even to society as a whole. This conflict is not unique to waste facility siting, but because of the potential for adverse impacts, the disparity may be seen as greater in waste management than in other activities.

Another nontechnical means of answering public concerns is for government to show convincingly its intent and ability to enforce hazardous waste regulations. Government officials can explain its monitoring and enforcement activities, and emphasize opportunities for public involvement, such as provisions for citizens' lawsuits. Evidence of a firm commitment in terms of funds and personnel can be particularly meaningful in times of restricted Federal and State budgets.

The California "superfund," enacted in 1981, establishes a tax-supported fund for compensating[80] victims of hazardous waste activities for their medical expenses and loss of income. New Jersey also provides a fund for victim compensation as part of its comprehensive hazardous waste siting strategy.

Even when the best waste management technology is proposed for use at the most carefully chosen location for a hazardous waste facility selected after the most open siting process, a residual of perceived adverse environmental and economic impacts is unavoidable. To compensate a community for these real or perceived risks, some form of incentive might be provided, unrelated to the hazardous waste facility itself. For example, government or the developer of a waste disposal facility could offer to finance public services for the community, for instance, as the purchase of fire equipment or the construction of a new community building, or the gift of land for a park. A developer can also take steps to prove a commitment to act as a good corporate citizen, e.g., by holding informal discussions to provide information or engage in negotiation, or by promising periodic public inspection of a waste management facility after it is operating.

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[80] Carpenter-Presley-Tanner Hazardous Substances Account Act, Statutes of 1981, ch. 756, California Health and Safety Code, Div. 20, ch. 6.8.

Role of the Federal Government

Direct Federal involvement in hazardous waste facility siting is virtually nonexistent. Few EPA regulations address siting issues. Some general site location standards are included, and the Agency has published a few reports describing the nature of siting problems. An expanded Federal role in siting is possible to assist States. EPA could develop model siting criteria, for example, or publish information on different approaches States have taken to the siting issue. These model siting criteria could include both technical and nontechnical means to address public concerns about siting. Alternatively, EPA could include siting criteria as a required element of State RCRA programs. The Federal Government, particularly the USGS, could play a stronger role in providing States with hydrogeologic information necessary to determine the suitability of locations for waste management facilities. Section 3005 of RCRA allows EPA to establish location standards for hazardous waste facilities. Establishment of national mandatory siting criteria, however, would probably require enabling legislation.

It has been suggested that Federal lands could be used for regional waste management sites thus facilitating site approval.[57] Because Federal lands are often remote, public opposition might be reduced. Long-term security of the site could be assured as the Government is unlikely to go "out-of-business." On the other hand, siting on Federal land may be viewed by many as an unfair subsidy to the hazardous waste management industry. It would shift some some costs of and responsibilities for waste management from private industry to the Government. In any case, siting facilities on Federal lands is primarily an option for Western States, as there is little available Federal land in the East. The idea is of little help to the east coast areas that have an immediate need for new facility sites.

A major function the Federal Government could serve is to facilitate exchanges of information among all the parties. Conferences, newsletters, information clearinghouses, and the like, give people the opportunity to learn from other's experiences. The Waste Alert Program funded by EPA was a good model for such an information exchange, but Federal funding has been discontinued.

Representatives of the Federal Government could act as formal or informal mediators arbitrating siting disputes. The Federal Mediation and Conciliation Service offers one model of Federal involvement, in its program of mediation and voluntary arbitration as a means of settling labor-management disputes. Similar dispute-resolution approaches have been suggested for environmental and land-use decisionmaking. The Massachusetts siting program includes, an as yet untested provision for negotiation and arbitration in facility siting agreements.

Another Federal role might be to help in the development of interstate hazardous waste management compacts, to ensure adequate disposal and treatment capacity regionwide. RCRA provides for the recognition of such interstate compacts for solid and hazardous waste management. They could be very useful in areas of the country where interstate transportation of hazardous waste is common. A precedent for Federal involvement is the assistance given by the Federal Government for negotiation of the multi-State water compacts to allocate rights to water from the Colorado River. It has been suggested that the Federal Government might require States to provide adequate management capacity for all waste generated in the States.

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[57] U.S. Environmental Protection Agency, "State Decisionmakers Guide for Hazardous Waste Management," SW-612, 1977.

Finally, the Federal Government might assist in the development of adequate compensation systems for victims of hazardous waste releases. The CERCLA 301(e) study group recently reported to Congress on the barriers to recovery of damages by victims of hazardous waste exposure under current law, and recommended the creation of a two-tier compensation system. The first tier would provide an expeditious Federal administrative compensation system. The second tier would improve existing State remedies by reducing the burdens of proof for injured claimants. The study group observed that the adoption of such a system might promote public acceptance of hazardous waste facilities.

Appendix 6A.—State Classification Efforts

The following tables provide examples of classification criteria developed by Washington, Texas, California, and Michigan.

A summary of the classification systems used in the feasibility study is presented. Further details can be obtained in the report prepared for OTA.[86]

The criteria for selecting these schemes addressed potential applicability to national regulations. Schemes that presented unique dimensions of hazard assessment were sought.

The Washington and Michigan schemes have several elements in common, including:

1. provision of management designations that prequalify facilities,
2. employment of toxicity rating systems that are based on waste constituent properties and not the entire waste stream,
3. provision of criteria and standards for evaluation, and
4. consideration of concentrations.

The Washington scheme is unique in that it involved the calculation of a single summary value representing the relative toxicity of a waste stream with multiple constituents. This summary value is called the waste's "equivalent concentration." Waste constituents are categorized according to their toxicity as defined by five classes related to four measures of acute toxicity. This method did not consider synergistic or antagonistic effects of constituents. Equivalent concentration is calculated by applying weighting factors to the five classes and summing concentrations of constituents. These concentrations are plotted against waste quantity using a graph that represents levels of regulation. Carcinogenicity is evaluated in a similar fashion based on the presence of halogenated hydrocarbons and polycyclic aromatic hydrocarbons. Three management levels are identified: undesignated, dangerous waste, and extremely hazardous waste.

The Michigan scheme involved the calculation of a hazard value for single constituents that is based on several waste characteristics other than just toxicity. This system used numerical ranking formulae that address acute toxicity, carcinogenicity, hereditary mutagenicity, teratogenicity, persistence, bioaccumulation, and other adverse chronic effects. Each constituent receives a score for all using available data. The formula applies a weighting scale to determine classes of toxicity. The constituents are not ranked according to accumulative scores. There are no provisions for lack of data. Once toxicity scores are assigned the constituent concentrations are plotted against waste quantity volumes on graphs specific for hazard categories.

The JRB system emphasizes environmental factors and waste management practices and was originally designed to evaluate land disposal sites containing hazardous waste to rank them for remedial action priority. This system involves the consideration of 31 site- and waste-specific variables which are grouped into four categories:

1. **Waste characteristics.**—The consideration of types of potential hazards posed by the waste.
2. **Waste management.**—The consideration of quality of the facility design, construction, and operation.

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[86] Harris, Strand, and Shea, op. cit.

3. **Pathways.**—The consideration of mechanisms of contaminant migration.
4. **Receptors.**—The identification of potential targets of chemical hazards.

A site is assigned a score of 0 to 4 for each of the 31 parameters. Each has an assigned weighting factor. A sum for all factors is calculated for each of the four evaluation categories. They are divided by the maximum possible score and multiplied by 100. The higher the score the greater the hazard posed by a facility.

Table 6A-1.—Criteria for the Washington System of Degree-of-Hazard Classification

	Extremely hazardous	Dangerous
Oral, rat, LD_{50}[a]	<500 mg/kg	<5,000 mg/kg
Aquatic fish, LC_{50}	<100 mg/l	<1,000 mg/l
Halogenated hydrocarbons	>1%	>0.01%
Polycyclic aromatics	>1%	None
Concentration of heavy metals in EPA leach test	10,000 × DWS[b]	100 × DWS
Nonbioaccumulative carcinogens	—	IARC[c] human or animal: positive or suspected
Corrosivity, reactivity, ignitability	—	EPA definition

[a] For pure compounds or simple mixtures book designation using the NIOSH Register and the designation diagram are possible, see appendix.
[b] DWS = drinking water standard.
[c] IARC = International Agency for Cancer Research. This group weighs published studies on suspected cancer causing agents and issues findings.

SOURCE: Provided by E. W. Tower, Solid Waste Management Division, Office of Land Programs, Department of Ecology, State of Washington, Olympia, Wash.

Table 6A-2.—Criteria for the Texas System of Degree-of-Hazard Classification

	Class I	Class II	Class III[a]
Hazard index[b]	<50	>50	>50
LD_{50} measures[c]	<500 mg/kg	>500 mg/kg	>500 mg/kg
pH[d]	<2.5, >12	2.5 – 12	2.5 – 12
Corrosion rate[e]	<0.25 in/yr	>0.25 in/yr	>0.25 in/yr
Flash point[f]	<140° F	>140° F	>140° F

[a] See text for compositional differences between Class II and Class III.
[b] Represents the potential hazard to the environment if improperly disposed, based on measures of toxicity and solubility of the substance.
[c] Median lethal dose; dose required to kill 50 percent of a population exposed to the chemical of concern.
[d] Measure of acidity or alkalinity; pH 7 indicates neutral solution; <pH 7 indicates acidic solution; >pH 7 indicates alkaline or basic solution.
[e] Corrosion rate on steel (SAE 1020) at a test temperature of 130°F as determined by NACE.
[f] Determined by a Pensky-Martens Closed Cup Tester using ASTM Std. D-93-73.

SOURCE: Sterling Hobe Corp. (12).

Table 6A-3.—Toxicity Criteria in the California System of Degree-of-Hazard Classification

	Limits[a]	
	Extremely hazardous	Hazardous
Mammals		
Oral administration	< 50 mg/kg[b]	<2000 mg/kg
Exposure to skin	<200 mg/kg	<1200 mg/kg
Inhaled	<200 mg/l	<4000 mg/l
Aquatic animals	—	< 500 mg/l
Carcinogenicity	Defined as carcinogen by California law	Defined as carcinogen by California law or suspected carcinogen by NIOSH listing
Tests in animals indicate	Carcinogenicity, high chronic toxicity, persistence, or bioaccumulative properties	Chronic toxicity, persistence or bioaccumulative properties

[a] Amounts that result in mortality for 50 percent of the test population. The lower the concentration the more toxic the material is to test organisms. LD_{50} for mammals and LC_{50} for aquatic animals.
[b] Mg of material/kg body weight of organism.

SOURCE: Sterling Hobe Corp. (12).

Table 6A.4.—Michigan's System for Rank-Order Assessment of Critical Materials

I. Acute toxicity

Score	Category		
	Oral LD_{50} mg/kg	Dermal LD_{50} mg/kg	Aquatic 96 hour LC_{50} mg/l
7	<5	<5	<1
3	5-50	5-200	1-10
2	>50-500	>200-500	>10-100
1	>500-5000	>500-5000	>100-1000
0	>5000	>5000	>1000
*	Insufficient information		

II. Carcinogenicity

Score	Category
7	Human positive; human suspect; animal positive
3	Animal suspect
2	Carcinogenic by a route other than oral or dermal; strong potential carcinogen by accepted mutagenicity screening tests or accepted cell transformation studies
1	Potential carcinogen by accepted mutagenicity screening tests or accepted cell transformation studies
0	Not carcinogenic
*	Insufficient information

III. Hereditary mutagenicity

Score	Category
7	Confirmed
4	Suspect - multicellular organisms
2	Suspect - micro-organisms
0	Not a hereditary mutagen
*	Insufficient information

IV. Teratogenicity

Score	Category
7	Confirmed
3	Suspect
0	Not teratogenic
*	Insufficient information

V. Persistence

Score	Category
4	Very persistent
3	Persistent
2	Slowly degradable
1	Moderately degradable
0	Readily degradable
*	Insufficient information

VI. Bioaccumulation

Score	Bioaccumulation	Log P
7	>4000	>6.00
3	1000-3999	5.00-5.99
2	700-999	4.50-4.99
1	300-699	4.00-4.49
9	<300	<4.00
*	Insufficient information	

VII. Esthetics

Score	Category	
	Fish tainting/taste and odor (threshold level in water - mg/l)	Foaming, floating film, and/or major color change
3	0.0001-0.001	
2	>0.001-0.01	
1	>0.01-0.1	Yes
0	>0.1	No

VIII. Chronic adverse effects

Score	Category
4	Irreversible effects
2	Reversible effects
1	Adverse effects by route other than oral, dermal or aquatic
0	No detectable adverse effects
*	Insufficient information

SOURCE: Michigan Department of Natural Resources (27).

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CHAPTER 7

The Current Federal-State Hazardous Waste Program

Summary Findings

- **Delays in implementation.**—Despite the simplicity of approach of the Resource Conservation and Recovery Act (RCRA), devising and implementing an effective program regulating hazardous waste with maximum public involvement mechanisms has proved to be a complex, controversial task. The Environmental Protection Agency's (EPA) implementation of requirements of RCRA section 3004 to establish performance standards for hazardous waste treatment, storage, and disposal facilities has been a process characterized by delay, false starts, frequent policy reversals, and litigation. Delays in rulemaking have meant delays in compliance with standards to protect human health and the environment, and uncertainty for States and industry. The delays may have been an additional incentive for some firms not to seek effective and economic measures to dispose of hazardous waste.
- **Universe of hazardous waste.**—Identification of a solid waste as hazardous is the key to RCRA's regulatory approach. The universe of hazardous waste is established by statutory definitions of solid and hazardous waste and EPA's interpretations of these definitions as further modified by various regulatory exclusions and exemptions. Many of these are not related to any determination of the actual hazard of the waste. **This ad hoc system of exclusions and exemptions allows certain potentially hazardous waste to escape proper management or oversight.** Exempted or excluded wastes, such as the small generator exemption, regardless of the reason for or the status of the exemption, can be disposed at subtitle D (municipal or sanitary) landfills that may not adequately control these wastes. Because of the design of these facilities, hazardous constituents may be released into the environment.
- **Lack of adequate, reliable, and verifiable information on which to base decisions.**—States, industries, and environmental groups have criticized the lack of information on: the amount and types of wastes, the effects of wastes disposal on the environment and on human health, and the adequacy of design, operating, and permitting requirements.
- **Inequities in application of regulatory requirements.**—The current RCRA regulatory system, because of its single hazard classification of wastes, and various exclusions from regulation (including exemptions of existing facilities from certain land disposal standards), has resulted in overregulation of some wastes and facilities and underregulation of others. Existing facilities have been required to meet differing standards of performance; for example, existing land disposal facilities do not have to upgrade their design and operations to the maximum extent feasible to receive a permit. However, existing incinerators are being required, in some places, to operate at the limits of available technology.
- **Lack of national consistency in hazard/risk determinations.**—Current regulations do present the opportunity to consider degree of hazard of wastes and levels of risk associated with particular facilities in setting permit conditions and granting variances from standards but only in the most qualitative and site-specific manner. Together with the frequent lack of objective Federal standards, this leads to little assurance of consistent levels of protection nationwide.
- **Continued use of inadequate waste management techniques.**—As a result of these delays in implementation, there has been continued reliance on landfilling and other

land disposal methods that have been proven inadequate to contain hazardous wastes. EPA's final land disposal regulations authorize continued use of these waste management practices by existing facilities.

- **No incentive for innovative technologies.** —The total national expenditure on hazardous waste activities, including the public and private sectors and RCRA and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) related efforts, was $4 billion to $5 billion in 1982. Combined Federal and State expenditures were in the range of $200 million to $300 million. Even at this level, the initial economic analysis of the current RCRA regulatory program suggests that it will not provide a sufficient economic incentive to internalize the true costs of hazardous waste disposal. Continued use of inadequate disposal practices will persist unless more effective means are implemented for internalizing costs and encouraging use of other management options through, for example, the imposition of waste generation fees. The need to resolve current problems is compounded by the realization that we may not be better equipped in the future, technologically or financially, to solve them. Because of the potential for wide-ranging impacts on environment and health, additional attention should be focused on promoting the use of alternative waste **treatment** or **destruction** technologies.

- **EPA's two-tiered approach for land disposal regulations.**—OTA's analysis of the design technology used in land disposal facilities indicates that complete containment of hazardous waste constituents over long periods of time (30 years or more) is not possible with the current technology. All land disposal sites eventually will release mobile constituents to the environment. The first tier of EPA's regulatory strategy for land disposal facilities, containment of hazardous constituents and liquid management, provides only temporary protection against contamination. The effectiveness of EPA's second-tier strategy of monitoring and corrective action also has substantial technical uncertainties. EPA's monitoring requirements may prove inadequate to detect leakage before substantial contamination has occurred. Moreover, **the long-term effectiveness of remedial action measures, which are relied on in EPA's second tier, such as ground water pumping, in situ treatment, and construction of barriers to ground water movement, has not been demonstrated.** Additionally, EPA's own economic analysis indicates that such measures can be extremely expensive, particulary if long-term corrective action is required. Given such costs, the financial capability of land disposal facilities to pay for necessary corrective action becomes a critical consideration in allowing continued use of such facilities.

- Current regulations for **monitoring** RCRA facilities are inadequate to provide assurance that the public health and the environment are being protected. EPA has emphasized only ground water monitoring. If land disposal of all hazard levels of wastes is allowed to continue (as the July 1982 rules seem to permit), it is essential that a rigorous ambient monitoring program be implemented at all such facilities. Without it there can be little assurance that exposure of humans and ecosystems to hazardous constituents will be prevented through early detection and prompt corrective action. Major problems include the following:
  - —The number and frequency of required sampling are such that large differences between background and new samples will be required before a statistically significant change in ground water quality is shown.
  - —Proper location of monitoring wells is essential to the effectiveness of an ambient monitoring program to measure background water quality and to provide early detection of possible ground water contamination. However, location of sampling wells during interim status is left to judgment of the facility owners. Final permit guidelines for well placement are equally vague.
  - —Due to limitations in the state of the art for analytical methodology, certain data re-

quirements for compliance monitoring of permitted land disposal facilities will be difficult to meet.

- The use of quantitative **risk assessment** in environmental regulation is receiving prominent attention within EPA and Congress. Available evidence suggests that the art of risk assessment is not sufficiently advanced to be reliable in some suggested applications to hazardous waste regulation. Moreover, much of the information required to perform such assessment is not yet available. Results of quantitative risk assessment must be interpreted with caution if they are to be incorporated into the decisionmaking process. The difficulties of using risk assessment tools are generated primarily by limitations of the assumptions used in these models. Generalizations may be inaccurate for specific sites, inadequate data bases may be used, criteria for assessing hazard and risk are lacking, and long-range performance cannot be predicted using currently available data.
- **Required insurance coverage** for hazardous waste facilities and increased civil liability have had, and will continue to have, a substantial impact on waste management strategies, but these measures largely complement, or supplement the regulatory programs. Moreover, insurers depend on **stringent** regulatory standards and enforcement as an incentive for them to underwrite the risks associated with hazardous waste facilities. The adequacy of regulatory requirements will influence the availability of required insurance coverage.
- Although **legal remedies** exist, private parties who are injured may not be compensated because of procedural and substantive difficulties involved in such cases, the costs and delays of litigation, and the problems of collecting damage judgments against absent or insolvent defendants.
- **Adequacy of funding and financial resources for implementation and enforcement.**—Concerns over the adequacy of funding for the Federal program and for Federal grants for State programs have been raised repeatedly as EPA has sought to reduce its regulatory budget. The need for adequate financing at the Federal and State levels may only increase as permitting of existing facilities proceeds. States will need additional funds to administer and enforce hazardous waste regulatory programs. On the average, about 75 percent of State hazardous waste program budgets come from Federal grants. **Existing State fees and taxes do not appear to be sufficient to finance their regulatory programs and cleanup actions.**
- **Lack of integration.**—Unlike major environmental statutes, such as the Clean Air Act (CAA) and the Clean Water Act, which are directed at control of pollution in a single environmental medium, RCRA's mandate for assuring proper hazardous waste management requires a multimedia approach to protect human health and the environment. Passage of RCRA unavoidably created an inherent potential for duplicative regulation of hazardous waste management under RCRA Subtitle C and regulation of environmental pollutants and control of hazardous substances under other Federal laws. Instead of leading to an all-inclusive integrated framework of environmental regulations providing better protection of human health and the environment, selective implementation of RCRA and other environmental laws has resulted in gaps in coverage so that some potentially serious impacts of hazardous waste activities have remained uncontrolled. For example, emissions of volatile organic chemicals from hazardous waste treatment, storage, and disposal activities are largely uncontrolled under RCRA and CAA regulations.
- **Extent of Superfund cleanup.**—The National Contingency Plan (NCP), the framework for Government action in cleaning up hazardous waste sites, does not establish any specific required environmental standard for the level of cleanup to be achieved, such as the maximum acceptable level of ground water contamination. EPA characterized the development of such standards for the hundreds (if not thousands) of substances that

could be found at uncontrolled sites as a potentially time-consuming and costly task that might detract from cleanup efforts. Nonetheless, EPA declined to specify cleanup standards even where they have already been set for other purposes. In contrast, the regulations for land disposal facilities require corrective action at permitted facilities to attain either background levels or the Safe Drinking Water Act standards. The NCP would allow contamination levels (that would trigger corrective action at permitted RCRA facilities) to continue to exist after remedial response actions have been taken or without requiring any response action at all.

- **State Superfund costs.**—States can nominate sites for inclusion on the National Priority List as candidates for Superfund cleanup and can designate one site in each State to be included in the 100 highest priority sites. CERCLA requires that States contribute at least 10 percent of the cleanup costs at privately owned sites and 50 percent or more at sites that were owned by a State when the hazardous substances were placed in them. However, States cannot determine which, if any, of their nominated sites will be cleaned up and when the cleanup will occur. This uncertainty makes it difficult for States to plan their own cleanup efforts and to arrange for financing of the required State contribution for Superfund actions. According to some State officials, proposed remedial actions at some National Priority List sites have not been taken because the States involved could not provide the required 10-percent share.
- **State responses to perceived inadequacies of Federal program.**—States are moving to more stringent requirements such as: limited bans on landfills, requirements for consideration of the use of feasible alternative technologies before approval of landfilling, imposition of hazardous waste fees and taxes, and establishment of strict liability standards for facility operators and generators for the consequences of hazardous waste activities. Many of these State actions were taken in response to the delays and perceived inadequacies in requirements of the Federal program.

Part I: Federal Regulation of Hazardous Waste Management

The Resource Conservation and Recovery Act

The basic framework for a comprehensive national regulatory program for the management of hazardous waste from generation to final disposal was established by Subtitle C of the Resource Conservation and Recovery Act of 1976 (RCRA).[1] This "cradle-to-grave" system consists of a minimum Federal program with the following major components:

- identification and listing of hazardous waste;
- a national manifest system for tracking wastes;
- standards for hazardous waste management treatment, storage, and disposal facilities; and
- a permit system for treatment, storage, and disposal facilities.

All hazardous waste activities would be subject to the Federal program, however, RCRA also provided for a State to exercise its primary administration and enforcement authority over hazardous waste in lieu of Federal regulation provided that the State program was as stringent, comprehensive, and effective as the Federal requirements.

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[1] Public Law 94-580, 90 Stat. 2795, Oct. 21, 1976, as amended by Public Law 95-609, 92 Stat. 3081, Nov. 8, 1978, the Solid Waste Disposal Act Amendments of 1980, Public Law 96-482 94, Stat. 2334, Oct. 21, 1980, and The Used Oil Recycling Act of 1980, Public Law 96-463, 94 Stat. 2055, Oct. 15, 1980. (Codified at 42 U.S.C. 6901 et seq.). Public Law 96-482 changed the title of RCRA to the Solid Waste Disposal Act. (In 1976, RCRA completely amended the Solid Waste Disposal Act of 1965, Public Law 89-272, 79 Stat. 997 (1965).) In this report, the Solid Waste Disposal Act will be referred to as RCRA in keeping with common usage.

The House Report on RCRA summarized the general advantage of having a Federal regulatory program, with optional implementation by the States.[2] There would be uniformity among the States as to how hazardous wastes are regulated; and uniform standards would be provided for industry and commercial establishments that generate such wastes. The establishment of this uniformity would also ensure that States which, for economic reasons, might otherwise decide to be dumping grounds for hazardous wastes will not attract businesses from States with environmentally sound laws.

The House Report added:

> The committee believes that Federal minimum standards are necessary if the hazardous waste problem is to be understood and solutions are to be found. Waiting for States to solve this problem without Federal assistance is not likely since each State would take a different approach and there would be too many gaps in both the receiving of information and enforcement.[3]

Subtitle C was part of the larger statutory scheme in RCRA for dealing with national solid waste disposal problems. Congress recognized that the hazardous waste problem presents serious dangers to health and the environment from improper disposal and very little information was available on which to establish effective policies. Accordingly, the conference committee report characterized the bill as "making the best of a bad situation," and gave the Environmental Protection Agency (EPA) broad authority to use its special expertise to define and identify hazardous waste and its characteristics and to develop a comprehensive system for the control of hazardous waste management and disposal. As additional mechanisms for responding to hazardous waste problems, Congress required maximum public participation in the process and provided access to courts for review of rulemaking and agency enforcement activities. RCRA includes an imminent hazard authority for immediate action to correct dangers posed by hazardous waste management activities and created civil and criminal penalties for improper hazardous waste activities.

RCRA is one of the simplest environmental laws enacted in the last decade. Unlike the Clean Air Act (CAA) and Clean Water Act (CWA) (which set many technical standards, emissions limits, and procedural requirements in the actual statutory language), RCRA leaves the task of designing and implementing a comprehensive regulatory system to EPA within the broad directive of a single overriding statutory goal—the protection of human health and the environment. Unlike implementation of air- and water-pollution control strategies that developed incrementally over more than a decade, Congress directed EPA to establish a comprehensive regulatory program defining the area to be regulated, the standards of protection, and a permitting system, all within a relatively short period of time.

The task was a large one. But faced with growing public concern and its own perceptions of the problem, Congress felt immediate action was required, even if the result might be overregulation of some substances. The RCRA scheme was sufficiently flexible to allow continued tailoring or fine tuning of the basic structure once it was established.

Despite the simplicity of RCRA's approach, devising and implementing an effective and timely program with maximum public involvement mechanisms has proved to be a complex and controversial task. It was widely believed that if RCRA was to result in a comprehensive hazardous waste management system, such a system would have the following essential attributes:[4]

1. A minimum Federal regulatory program would control and define the universe of regulated hazardous waste, which would evolve in response to greater knowledge about the hazards of the wastes and their interactions with public health and the environment.

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[2] House Report 94-1491; 94th Cong., 2d sess. (1976), at 30.
[3] Id.
[4] See generally, House Report 94-1491, supra note 2, at 24-32.

2. The combined Federal and State programs would promote the availability of adequate treatment and disposal capacity.
3. The program would encourage generators to use process modification, product substitution, and recycling to reduce the volumes of wastes generated.
4. The program would receive adequate funding through Federal assistance to States (and other mechanisms).
5. Permitting and enforcement responsibilities eventually would be handled primarily by the States with Federal oversight.
6. The system would promote public participation in rulemaking (setting of standards) and permitting of facilities and would recognize private lawsuits to alleviate hazardous waste problems in the absence of effective Federal or State action.
7. The act's criminal and civil penalties for noncompliance would be a further incentive to comply with standards.
8. The regulatory program would require financial responsibility of those parties engaging in hazardous waste activities and would end the system of anonymous dumpers and unmarked, unrecorded sites.
9. The comprehensive regulatory system would force internalization of the true costs of hazardous waste disposal and eventually would assure that hazardous wastes are properly disposed, protecting public health and the environment.
10. The system would combine onsite treatment of some wastes with offsite treatment for others and secure land disposal methods for residues that remain hazardous after treatment.

The Federal hazardous waste regulatory system still falls short of the ambitious goals of RCRA. In the more than 6 years since passage of RCRA, in 1976, implementation of the act through required rulemaking by EPA has been slow. Many important statutory deadlines were missed and several major regulations were promulgated only after court orders directed EPA to meet its responsibilities. Among the reasons cited by EPA for these delays were budgetary limitations, need for more scientific and technical information, and the complexity of developing a comprehensive regulatory program based on a general statutory mandate.[5] On July 26, 1982, EPA issued interim final regulations governing land disposal facilities and final authorization of State regulatory programs. When the land disposal regulations became effective on January 26, 1983, the basic Federal regulatory program for hazardous waste activities was in place. EPA acknowledges that the program is not complete—standards for permitting chemical and biological treatment facilities have not yet been promulgated, for example, and further modifications and additions to the rules already in effect will be made. However, the institutional framework has been established by which most existing and new facilities can be permitted, and State programs can receive final authorization to operate in lieu of the Federal program. **According to EPA, full implementation of RCRA through issuance of detailed technical standards, permitting of all existing facilities, and final approval of State programs likely will take an additional 5 to 7 years.**

Identification and Classification of Hazardous Waste—The Trigger

Hazardous waste enters the system at the point at which it is generated. Under EPA rules, each generator of solid waste must analyze its wastes to determine whether there is hazardous waste. If waste is a hazardous waste and not exempted by statute or rule, it must be managed in compliance with EPA regulations or the requirements of an approved State regulatory program. The waste must be properly packaged and manifested if shipped offsite, and must be sent for treatment, storage, or disposal only to a hazardous waste facility operated according to EPA standards.

The requirements of the RCRA Subtitle C regulatory program are triggered by the identification of a solid waste as hazardous waste.

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[5] See preamble to EPA land disposal regulations, 47 F.R. *33,276-33,278,* July 26, 1982 which summarizes the history of and changes in EPA's implementation of subtitle C.

The universe of hazardous waste is established by statutory definitions and EPA's regulatory interpretations of these definitions are further modified by various statutory and regulatory exclusions and exemptions. **Solid waste** is defined in section 1004(27) of RCRA as:[6]

> . . . any garbage, refuse, sludge . . . and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities . . .

Hazardous waste is defined in section 1004(5) of RCRA as:[7]

> . . . a solid waste, or combination of solid waste, which because of its quantity, concentration, or physical, chemical, or infectious attributes, may:
>
> (A) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or
>
> (B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

Section 3001 of RCRA directs EPA to develop: 1) criteria for identifying the characteristics of hazardous waste and 2) criteria for listing particular hazardous wastes. In adopting these criteria, section 3001 requires EPA to take into account "toxicity, persistence, and degradability in nature, potential for accumulation in tissue, and other related factors such as flammability, corrosiveness, and other hazardous characteristics." Using the characteristics and listing promulgated based on theses criteria, EPA is to define the universe of hazardous waste to be regulated (see table 51).

Exclusions From the Definitions of Solid Waste and Hazardous Waste

RCRA excludes from this definition of solid waste certain materials that are regulated under other Federal laws or that would be impractical to regulate under the RCRA scheme. These statutory exclusions from the definition of solid waste and thus from the universe of hazardous waste are: materials in domestic sewage and irrigation return flows, industrial point source discharges permitted under CWA, and source, special nuclear, or byproduct material defined under the Atomic Energy Act of 1954, as amended.

Table 51.—Identification of Hazardous Waste

Is it a solid waste?

The material is an RCRA solid waste if:

1. It is garbage, refuse or sludge, or other solid, liquid, semiliquid or contained gaseous material that:
    a. is discarded or is sometimes discarded, or
    b. has served its original intended purpose and is sometimes discarded; or
    c. is a manufacturing or mining byproduct and is sometimes discarded; and
2. It is not excluded from the definition of RCRA solid waste by statute or rule.

If the waste meets the above two conditions, it is a RCRA solid waste irrespective of whether it is discarded, used, reused, reclaimed, or recycled, or stored or accumulated before such activities.

Materials that do not meet these conditions are not RCRA solid wastes and cannot therefore be regulated as hazardous waste.

Is it a hazardous waste?

A material will be considered as RCRA hazardous waste if it meets the following conditions:

1. It is a RCRA solid waste and is not excluded from regulation by statute or rule;
2. The waste is listed as hazardous waste or is a mixture containing a listed waste, and the waste or mixture has not been specifically delisted; or the waste (or a mixture containing the waste) exhibits one of the characteristics of hazardous waste: ignitability, reactivity, corrosivity, or EP toxicity.
3. The waste has not been excluded by statute or rule from the definition of hazardous waste.

SOURCES: 40 CFR 261.4(b); 40 CFR 261.3, 260.20, 260.22; and 40 CFR 261, Subpart G.

EPA has further interpreted the meaning of solid waste for purposes of hazardous waste regulation as a material that:

- is discarded, or being stored, or physically, chemically, or biologically treated before being discarded; or
- has served its original intended use and is sometimes discarded; or
- is a mining or manufacturing byproduct and is sometimes discarded.[8]

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[6] 42 U.S.C. 6903 (14).

[7] 42 U.S.C. 6903 (5).

[8] 40 CFR 261 (1982).

The heart of EPA's regulatory definition is that the material is discarded or sometimes discarded. EPA defines discarded as "abandoned (and not used, reused, reclaimed or recycled) or disposed of or burned or incinerated or otherwise treated instead of, or before, being disposed of." This broad regulatory concept of solid waste excludes primary and intermediate industrial, commercial, mining, and agricultural manufacturing products, but asserts jurisdiction over the broad range of activities involving recycling, reclamation, and reuse. Materials that are recycled, reclaimed, or reused are not regulated only when that is the universal practice in the industry.

There are two important regulatory exclusions from the definition of solid waste. EPA excepts the burning or incineration of solid waste as a fuel for the purpose of recovering usable energy from the meaning of "discarded" and thus from being a solid waste. EPA also has excluded materials subject to in situ mining techniques which are not removed from the ground as part of the mining process from the definition of solid waste.

The Solid Waste Disposal Act (SWDA) Amendments of 1980 temporarily exclude from regulation under Subtitle C of RCRA, hazardous wastes from oil, gas, and geothermal energy exploration and production; from burning of coal and other fossil fuels; from mineral mining and processing, and cement-kiln dust waste.[9]

EPA is to study these wastes and to report back to Congress with recommendations on whether they should be regulated under Subtitle C of RCRA.* During the study period, management of these wastes will be regulated under other Federal and State laws, including Subtitle D of RCRA. The amendments provide that EPA may promulgate regulations governing disposal of fossil fuel combustion, mining, and cement-kiln dust wastes under section 2002 of RCRA that require placing in the public record the location of any closed disposal sites and an analysis of the wastes deposited there. This temporary exclusion is effective until at least 6 months after submission of the required report to Congress and promulgation of regulations on these wastes, or publication of EPA's determination based on these studies that such regulations are unwarranted. For oil, gas, and geothermal wastes, the amendments include a "sense of the Congress" provision that existing Federal and State regulatory programs governing these wastes during the interim period should require at a minimum the recording of the location of any waste disposal sites that are closed and an analysis of produced waters and drilling fluids deposited there that are suspected of containing hazardous substances. The temporary exclusion for drilling fluids, produced waters, and other wastes for oil, gas, and geothermal energy exploration, development, or production is effective until Congress approves any regulations recommended by EPA as a result of the study.

In addition to the statutory exclusions, EPA's regulations interpreting the statutory provisions exclude certain solid wastes from the definition of hazardous wastes for the purpose of subtitle C.[10] These exclusions are shown in table 52.

A solid waste is a hazardous waste if it is not excluded from regulation as a hazardous waste and it meets any of the following criteria:

- it is listed by EPA in 40 CFR 261, subpart D, and has not been specifically delisted; or
- it is a mixture of a listed waste and a solid waste and has not been specifically delisted; or
- it exhibits any of the four characteristics for identifying hazardous waste in 40 CFR 261, subpart C: ignitability, corrosivity, reactivity, and extraction procedures (EP) toxicity.

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[9] Public Law 96-482, sec. 7, 94 Stat. 2336, Oct. 21, 1980; 42 U.S.C. 6921.

*The EPA studies are to look at items such as: 1) the source and volume of the waste, 2) present disposal/utilization practices, 3) potential danger to human health or the environment, 4) documented cases of proven danger, 5) alternatives to current disposal practices, 6) cost of alternatives, 7) impact of alternatives on the use of natural resources, and 8) current and potential use of these materials.

[10] 40 CFR 261.4 (1982).

Table 52.—Exemptions and Exclusions From the Universe of Hazardous Waste

Exclusions from the statutory definition of solid waste:
- solid or dissolved materials in domestic sewage;
- solid or dissolved materials in irrigation return flows;
- industrial discharges that are point sources subject to National Pollutant Discharge Elimination System (NPDES) permits under sec. 402 of the Clean Water Act; and
- source, special nuclear, or byproduct material defined under the Atomic Energy Act of 1954, as amended.

Exclusions by rule from the definition of solid waste:
- statutory exclusions above;
- waste burned as fuel for purposes of recovering usable energy; and
- in-situ mining wastes not removed from the ground.

Temporary statutory exclusions from the definition of hazardous waste:
- drilling fluids, produced waters and other wastes associated with the exploration, development, or production of crude oil, natural gas, or geothermal energy;
- fly ash waste, bottom ash waste, slag waste, and flue gas emission control waste generated primarily from combustion of coal or other fossil fuels;
- solid waste from the extraction, beneficiation, and processing of ores and minerals, including phosphate rock and the overburden from the mining of uranium ore; and
- cement kiln dust waste.

Solid wastes excluded from the definition of hazardous wastes in EPA regulations:
- household waste;
- agricultural and livestock raising wastes used as fertilizers;
- mining overburden returned to the minesite;
- temporary statutory exclusions above;
- certain wastes containing exclusively (or almost exclusively) trivalent chromium from leather tanning and finishing industries, shoe manufacturing and other leather product industries, and wastewater treatment sludge from production of TiO_2 pigment from chromium-bearing ores by the chloride process (if not hazardous under any other provision except failure of EP toxicity test for chromium);
- solid waste from coal mining and processing;
- arsenical treated wood or wood products which: 1) fail the test for EP toxicity and 2) are discarded by persons using the wood or wood products for its intended end use (unless the waste meets other tests for hazardous waste);
- any waste, sludge, or residue for hazardous waste treatment that is no longer hazardous because it no longer displays a characteristic of hazardous waste;
- hazardous waste generated in a product or raw material storage tank, transport vehicle, or in a closed manufacturing process unit or waste treatment unit before it exits from or is removed from the unit;
- samples of solid waste, or of water, soil, or air collected solely for testing subject to special handling requirements to qualify for this exemption); and
- a delisted solid waste or sludge or residue from treatment of a delisted hazardous waste (provided that it does not exhibit any characteristics of hazardous waste).

SOURCE: 40 CRF 261 Subpart C.

Hazardous Waste Characteristics

Section 3001 of RCRA requires that EPA develop and promulgate criteria to be used to identify the characteristics of hazardous waste. A waste which exhibits any of these characteristics will be considered as a regulated hazardous waste. EPA regulations use the statutory definition of hazardous waste—i.e., the potential effects that exposure to such waste may have on human health or the environment as two of these criteria. The third criteria is that the characteristics must be capable: 1) of being measured by standardized testing protocols that are reasonably within the capabilities of the regulated community or 2) of being reasonably detected by generators of solid waste through their own knowledge of their waste stream. Using these critieria, EPA identified four characteristics:

- ignitibility—posing a fire hazard during routine management;
- corrosivity—ability to corrode standard containers or to dissolve toxic components of other wastes;
- reactivity—tendency to explode under normal management conditions, to react violently when mixed with water, or to generate toxic gases;
- EP toxicity (as determined by a specific extraction procedure)—presence of certain toxic materials (as listed in 40 CFR 261.24) at levels greater than those specified in the regulation.

Table 53 shows in more detail the tests to be used in determining whether a waste exhibits a hazardous characteristic.

Other properties of some solid wastes that pose a threat to health and the environment, such as carcinogenicity, teratogenicity, infectiousness, and mutagenicity, are not included in the characteristics for identifying hazardous wastes because EPA considers that reliable testing protocols for these effects are not generally available to the regulated communi-

Table 53.—Characteristics of Hazardous Wastes

Ignitability—(wastes that during routine handling could start fire or exacerbate fire once started):

- liquid with a flash point below 60° C (140° F);
- nonliquid capable under standard temperature and pressure of causing fire through friction, absorption of moisture, or spontaneous chemical changes, and, when ignited, burns so vigorously and persistently that it creates a hazard;
- ignitable compressed gas as defined by the U.S. Department of Transportation; and
- oxidizer as defined by the U.S. Department of Transportation.

Corrosivity—(wastes that under normal conditions could corrode through their containers and leach out other waste constituents):

- aqueous material with pH less than or equal to 2 or greater than or equal to 12.5; or
- liquid that corrodes steel at a rate greater than 6.35 millimeters (0.25 inch) per year under specified test procedures.

Reactivity—(wastes that are extremely unstable under normal conditions with tendency to react violently, explode, or give off dangerous gases):

- normally unstable material that readily undergoes violent change without detonating; or
- material that reacts violently with water; or
- material that forms potentially explosive mixtures with water, or when mixed with water generates toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment; or
- a cyanide or sulfide-bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment; or
- material that is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement or it is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure; or
- a forbidden explosive, Class A explosive, or Class B explosive, as defined by U.S. Department of Transportation regulations.

Toxicity—(wastes are likely to leach out hazardous concentration of toxic chemicals.) Waste is "EP toxic" if a specified extraction procedure test yields an extract equal to or exceeding following levels:

Contaminant	*Maximum concentration (milligrams per liter)*
Arsenic	5.0
Barium	100.0
Cadmium	1.0
Chromium	5.0
Lead	5.0
Mercury	0.2
Selenium	1.0
Silver	5.0
Endrin	0.02
Lindane	0.4
Methoxychlor	10.0
Toxaphene	0.5
2,4-D	10.0
2,4,5-TP Silvex	1.0

SOURCE: 40 CFR 261 Subpart C.

ty. Waste exhibiting these characteristics, however, may be brought under the subtitle C regulations through the listing mechanism.

Each generator must determine if a solid waste exhibits one or more of the specified characteristics by testing a "representative sample" of the waste. The testing may be based on protocols described in the regulations, on other protocols approved by EPA as "equivalent," or the generator may simply apply his own knowledge of the solid waste or its constituents.

Unlike mixtures containing **listed** wastes (which are automatically considered hazardous), mixtures containing unlisted waste are considered hazardous and subject to regulation **only** if the **entire** mixture exhibits one or more of the specified characteristics.

Listing of Hazardous Waste

The second method for determining if a solid waste is a hazardous waste is whether the waste is listed as a hazardous waste or is a mixture of a solid waste and a listed waste. Section 3001 of RCRA requires EPA to develop criteria to be used in listing particular hazardous wastes and waste streams. The listing criteria are that the solid waste:

- exhibits one of the four characteristics of hazardous waste (ignitability, corrosivity, reactivity, or EP toxicity); or
- has been found to be fatal in humans in low doses or, in the absence of human data, has been shown to be dangerous in animal studies; or is otherwise capable of causing or significantly contributing to an increase in serious irreversible, or incapacitating reversible, illness (such waste is designated **"acute hazardous waste"**); or
- contains any of the toxic constituents listed in Part 261, Appendix VIII which have been shown in scientific studies to have toxic, carcinogenic, mutagenic, or teratogenic effects on human or other life forms, unless it is determined that the waste cannot pose a hazard when improp-

erly managed. This class of waste is designated **"toxic waste."**

Based on these criteria and available scientific and technical information, in May 1980, EPA published three generic lists of wastes that are considered to be hazardous and subject to RCRA Subtitle C regulation:

1. hazardous waste from nonspecific sources (40 CFR 261.31);
2. hazardous waste from specific sources (40 CFR 261.32); and
3. discarded commercial chemical products, off-specification species, containers, and spill residues thereof (40 CFR 261.33). The discarded commercial chemical products list is further divided into wastes designated as **toxic wastes** (40 CFR 261.33(f)) and as **acutely hazardous wastes** (40 CFR 261.33(e)).

Any listed waste is regulated unless it is delisted either through removal of the listing of the generic waste or of the specific waste from a particular facility in response to a petiton for regulatory amendment.

Delisting of Hazardous Waste[11]

Because the lists of hazardous waste include a broad range, it may subject some wastes or individual generators to regulation in circumstances when their wastes do not pose a threat to human health or the environment even when improperly managed. To deal with the potential for "overregulation," frequently inherent in precautionary health and safety regulatory schemes involving complex scientific and technical issues, EPA has provided an "escape hatch" through the delisting process.

Delisting is accomplished by petitioning for a regulatory amendment as authorized under section 7004 of RCRA. A delisting petition as a rulemaking procedure is subject to requirements for public notice and comment. Delisting petitions generally fall into one of two categories. One type of petition seeks a determination that a listed waste from a **particular generator** is not hazardous by demonstrating that this specific waste under its individual circumstances does not meet any of the criteria that caused the waste to be listed generically. If the petition is granted, waste from that generator only is no longer considered as listed hazardous waste. The second type of petition seeks to remove a listed waste from the hazardous waste lists by demonstrating that EPA erred in its original generic listing and that the waste in fact does not meet any of the criteria for listing. If a **generic delisting petition** is granted, the waste is no longer listed hazardous waste. The delisting provision allows consideration of the variations in individual waste streams resulting from differences in raw materials, industrial process technologies, and other factors. It provides an incentive for some firms to modify their processes or products so that their wastes are not classified as hazardous wastes. By September 30, 1982, over 200 delisting petitions had been submitted to EPA and were under review.

EPA rules provide for the granting of a **temporary exclusion** based on a finding of substantial likelihood that a delisting petition will ultimately be granted. **Temporary exclusions can be issued without advance public notice or opportunity for comment, however, EPA retains an opportunity to reconsider its decision in the future based on new information received in response to request for comments published when the temporary exclusion is granted.** Several environmental groups have criticized granting a temporary exclusion without the procedural safeguards of public notice and comment. These groups contend that temporary exclusions lifting the requirements for proper management and tracking of the waste could result in inadequate protection of health and the environment, during the interim before a final determination is made, if more detailed review in response to public comment indicated that the waste was properly listed as hazardous. On several occasions, EPA has granted such temporary exclusions without prior opportunity for public comment.[12] In some cases

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[11] 40 CFR 260.20 and 260.22 (1982).

[12] See, for example, temporary exclusions at 47 F.R. 52,667, Nov. 22, 1982.

EPA's final determination later modified its temporary exclusion based on the comments received and more intensive review.[13]

The delisting of a facility's waste does not mean that it is not subject to hazardous waste regulation. The facility must continue to analyze its solid waste, and if it exhibits one of the four characteristics of hazardous waste or if it later includes a listed waste, the waste is subject to subtitle C regulations. Generators have the burden of demonstrating that their waste is not hazardous because under RCRA they are responsible for determining whether their wastes are hazardous, and because they are uniquely aware of the contents of their waste streams.

Changes in the Universe of Hazardous Waste

In general, because of various exemptions and exclusions and the listing and delisting processes, the universe of waste covered by the RCRA Subtitle C regulations can be expected to change. Moreover, EPA is required to review periodically the lists and the criteria for identifying waste, and to make appropriate additions and deletions as more information becomes available. **However, EPA has not made any additions to the list of hazardous waste since 1980.** Under section 3001(c) of RCRA, State governors may also petition EPA to add substances to the list. The Governor of Michigan, for example, has submitted a petition requesting that EPA add over 200 additional chemical substances regulated as hazardous waste in Michigan to the Federal list of hazardous wastes.

Special Exemptions for Certain Categories of Hazardous Wastes

All wastes in the universe of hazardous waste are not necessarily subject to the full requirements of the RCRA program. For example, EPA regulations include special limited exemptions for generators which produce hazardous waste in small quantities, for hazardous wastes that are used, reused, recycled, or reclaimed, and for residues of hazardous wastes in containers. These limited exemptions have the advantage that EPA retains regulatory jurisdiction over the wastes and activities involved and could impose additional requirements or invoke its enforcement authority where necessary to protect human health or the environment.

Small Quantity Generator Exemption

EPA has exempted certain small quantity generators from the standards generally imposed on hazardous waste generators. These small generators are exempted from the notification, recordkeeping, reporting requirements, and from the manifest system. As a consequence of this exemption, unknown quantities of hazardous waste exit the regulated universe of hazardous waste. In the preamble to the May 1980 regulations, EPA explained its reason for creation of this administrative exemption because:

> . . . (the) enormous number of small generators, if brought entirely within the subtitle C regulatory system, would far outstrip the limited Agency resources necessary to achieve effective implementation.[14]

To qualify for the the small quantity generator exemption, generators must not generate or accumulate more than a specified amount of hazardous waste each month. The small quantity limits are:

- no more than 1 kilogram per month (kg/mo) for acutely hazardous waste,
- no more than 100 kg/mo of residues or contaminated soils, water, or other debris resulting from the cleanup of any spill of any acutely hazardous waste; or
- no more than 1,000 kg/mo (2,200 lb) of any other hazardous waste.[15]

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[13] See 47 F.R. 52,667, Nov. 22, 1981, at 52,685.

[14] 45 F.R. 33,104, May 19, 1980.

[15] Identified in 40 CFR 261, subpart C (1982). Many States have been more restrictive than EPA in granting exemptions for some of the small quantity generators. In some States, small quantity generators are thought to be responsible for the most serious hazardous waste problem. See the discussion of State small generator provisions later in this chapter.

In addition, the generator must either treat or store the hazardous waste in an onsite facility or ensure delivery to an approved offsite storage, treatment, or disposal facility. This offsite facility must be a facility that has interim status or is permitted under the Federal RCRA program or an authorized State program, a State-approved municipal or industrial solid waste facility (subtitle D facility), or a facility that beneficially uses or reuses or legitimately recycles or reclaims the waste or treats it before such reuse or recycling.

Small quantity generators who mix hazardous waste with nonhazardous waste may take advantage of the small quantity exemption provided that the amount of hazardous waste in the mixture remains below the specified limits and that the mixture does not exhibit any of the characteristics of hazardous wastes.

Exemption for Wastes That Are Used, Reused, Recycled, or Reclaimed

EPA has recognized the need to achieve a workable balance between the requirement in subtitle C that hazardous waste be properly managed and RCRA's overall objective of promoting the use, reuse, recycling, and reclamation of energy and material from wastes. Despite objections that regulation might thwart the resource recovery goals of RCRA, EPA has included hazardous wastes that are used, reused, recycled, or reclaimed within the universe of hazardous waste, but has temporarily exempted many of these wastes from most hazardous waste regulation until special provisions can be developed.

Listed hazardous wastes, mixtures containing listed hazardous wastes, and sludges, which are transported or stored before being recycled, are subject to limited notification, recordkeeping, transportation, and storage requirements. However, other hazardous wastes are exempted from regulation altogether if they are:

- being beneficially used or reused or legitimately recycled or reclaimed; or
- being accumulated, stored, or physically, chemically, or biologically treated prior to beneficial use or reuse or legitimate recycling or reclamation; or
- spent pickle liquor reused in wastewater treatment in a National Pollutant Discharge Elimination System (NPDES) permitted facility or that is being stored or treated before such use.[16]

Exemption for Residues of Hazardous Waste in Empty Containers

EPA has decided that any hazardous waste residues remaining in an "empty" container, or in an inner liner removed from an "empty" container, are not subject to hazardous waste regulation. A container is considered "empty" if:

- it has held a hazardous waste that is a compressed gas, but the pressure in the container now approaches atmospheric; or
- it has held an acutely hazardous commercial chemical, but has since been triple-rinsed with an appropriate solvent or cleaned by some other means shown to achieve equivalent removal; or
- it has held any other type of hazardous waste, but all waste has since been removed using the practices commonly used to remove materials from that kind of container (e.g., pouring, pumping, aspirating) and no more than 2.5 centimeters (1 inch) or 0.3 percent by weight of residue remain on the bottom of the container or inner liner.[16]

If a container is not "empty" according to one of these three definitions, then any hazardous waste remaining in the container is subject to full regulation unless the generator qualifies for the small generator exemption or the container residues qualify for the recycling exemption.

Provisions of General Applicability to Hazardous Waste Generators, Transporters, and Treatment, Storage, Disposal Facilities

Notification

Section 3010 of RCRA[17] requires that all generators, transporters, and owners or operators of treatment, storage, and disposal facilities (TSDFs) must have notified EPA that they are handling hazardous waste within 90 days of the date EPA issues rules defining hazardous waste (i.e., by Aug. 19, 1980). The generation, transportation, treatment, storage, or disposal of hazardous waste after that date is illegal if the required notification has not been made.

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[16] 40 CFR 261.7, as modified at 47 F.R. 36092, Aug. 18, 1982.
[17] 42 U.S.C. 6930.

EPA encountered practical difficulties in applying the notification requirement to firms that engaged in hazardous waste activities after the initial notification date had passed but that had not been in violation of the requirements on that date. (For example, small generators who later exceeded the permissible 1,000 kg/mo level, generators whose wastes were listed subsequent to the date.) Accordingly, EPA provided that such firms are not in violation of section 3010 if they were not required to notify EPA on the Aug. 19, 1980 notification date. These firms must notify EPA that they are engaged in hazardous waste activities after they become subject to regulation.

The Manifest System

RCRA provides that EPA regulations must require that waste generators, transporters, and TSDFs comply with the manifest system. The manifest system is an integral part of the comprehensive hazardous waste regulatory scheme under RCRA as envisioned by Congress. **All waste shipped offsite of generation must be manifested; the manifest must accompany the waste and identify the waste; specify its quantity, origin, and destination; and the identity of the transporter. The manifest allows tracking of the waste for enforcement. The manifest requirement also works to discourage the practices that produced midnight dumping and orphan dump sites.** Additionally, it provides information on which to base regulation. The requirement is largely self-executing because it relies on the regulated community to monitor compliance and to report possible violations.

Originally, EPA declined to establish a uniform national manifest. Consequently, States imposed their own manifest requirements. Interstate shippers of hazardous waste faced the possibility of having to carry a different manifest for each State they traveled through. In practice, however, many States accepted manifests of other States for purposes of complying with their requirements if the necessary identifying information was included. **In response to industry complaints about lack of uniformity, EPA has proposed, but not yet finalized, a national manifest form.**[18]

Regulation of Hazardous Waste Generators

RCRA places several critical responsibilities on generators of hazardous wastes. The generator is responsible for assuring that hazardous waste enters the regulatory system by analyzing its solid waste to determine whether it is a regulated hazardous waste. If it is, the generator must meet notification and reporting requirements, prepare a manifest for shipping waste offsite, and properly pack and label the waste for shipment. Generator activities are not, however, as directly controlled as those of hazardous waste TSDF operators. The 1980 RCRA Amendments to section 3002 emphatically placed on the generator the responsibility **to assure** that waste is transported to, and arrives at, an appropriate facility.[19]

EPA regulations define a generator as:

> . . . any person, by site, whose act or process produced hazardous waste identified or listed in part 261 of this chapter and whose act first causes hazardous waste to become subject to regulation.[20]

EPA's definition of generator means that each individual plant or facility that produces hazardous waste is considered a separate generator. The definition of generator does not distinguish between those who produce hazardous waste as a normal consequence of their activities or processes, or those who create hazardous waste as a result of an accident or other unusual circumstances. Exclusion of some substances (e.g., mine waste) from the definition of hazardous waste has the effect of removing the firms that produce these substances from being considered as generators and from having to comply with reporting and recordkeeping requirements. Additionally, a generator must obtain a TSDF permit if the waste is accumulated on the property for more than 90 days or if the generator treats or disposes of the waste on site.[21]

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[18] 47 F.R. 9,336, Mar. 4, 1982.
[19] 42 U.S.C. 6922.
[20] 40 CFR 260.10 (1982).

Requirements for Transporters of Hazardous Waste

RCRA directs EPA to establish standards for transporters of hazardous waste. Safe transport of hazardous waste from generators to disposal sites is an important part of the comprehensive regulatory system. Requirements for hazardous waste transport were included to allow tracking of wastes and to prevent the abuses of midnight dumpers as well as the safety threats posed by moving hazardous waste materials unlabeled and undisclosed in interstate commerce and from accidents.

Section 3003 of RCRA provides for EPA to issue regulations for transporters which include requirements for recordkeeping, compliance with the manifest system, transportation only of properly labeled and packaged waste, and transportation of the waste only to the permitted or interim status TSDFs designated on the manifest.[22] Transporters are not themselves required to have permits under RCRA, but they must obtain identification numbers from EPA and they may not accept waste from generators who do not also have identification numbers.

Transporters of hazardous waste are subject to both EPA's regulations under RCRA[23] (or those issued under an approved State program), regulations issued by the Department of Transportation (DOT) under the Hazardous Materials Transportation Act[24] (many of which have been jointly adopted with EPA), and any additional requirements of State laws. RCRA imposes two additional responsibilities to the DOT hazardous materials regulatory scheme: notifying of hazardous waste activities and obtaining an EPA identification number and complying with the manifest system. The RCRA regulations do not apply to onsite transportation of hazardous waste by generators or by owners or operators of TSDFs. They also do not apply to transporters of waste from small quantity generators or (except for limited provisions) to transporters of recycled waste or empty containers, because of their exclusion from most of the subtitle C regulatory system.

Special rules may apply when a discharge occurs during transportation (i.e., when there is an accidental spilling, leaking, pumping, emptying or dumping of hazardous waste onto or into the land or water. Furthermore, transporters who hold waste for more than 10 days (except under limited circumstances) must comply with the applicable regulations for storage and for obtaining a RCRA storage facility permit.[25]

Requirements for Hazardous Waste Treatment, Storage, and Disposal Facilities

Section 3004 of RCRA authorizes EPA to promulgate "such performance standards for hazardous waste treatment, storage, and disposal facilities as may be necessary to protect human health and the environment." The 1980 amendments require EPA to distinguish, where appropriate, between new and existing facilities in setting these standards.[26]

The performance standards are intended to serve a threefold purpose:

1. to establish design and operating practices that are adequate to protect health and environment,
2. to provide the technical basis for permitting facilities, and
3. to set minimum standards for authorizing State hazardous waste programs.

Section 3004 provides that the EPA performance standards must include, but are not limited to, requirements for:

- maintenance of records of all hazardous wastes handled by the facility and of treatment, storage, or disposal practices used;

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[21] 40 CFR 262.34 (1982).
[22] 42 U.S.C. 6923.
[23] 40 CFR part 263 (1982).
[24] 49 U.S.C. 1801-1812, (1978).

[25] John Quarles, *Federal Regulation of Hazardous Waste: A Guide to RCRA* (Washington, D.C.: Environmental Law Institute, 1982), pp. 66-67.
[26] 42 U.S.C. 6924.

- reporting, monitoring, inspections, and compliance with the manifest system;
- operating methods, techniques, and practices for treating, storing, or disposing of hazardous wastes;
- location, design, and construction of the facility;
- contingency plans for effective action to minimize unanticipated damage from hazardous waste treatment, storage, or disposal;
- maintenance of operation of the facility and such additional qualifications as to ownership, continuity of operations, training for personnel, and financial responsibility as may be necessary or desirable; and
- compliance with the requirements of RCRA section 3005 relating to permits for facilities.

Performance standards commonly are used to establish the level of effectiveness that a pollution control technology or managerial practice must achieve—e.g., a requirement that a landfill-liner system must prevent waste constituents from entering the environment for 200 years is a possible formulation of a performance standard. The use of the term "performance standard" in section 3004, however, is to be given a broad meaning since the objective to be met is the "protection of human health and the environment" from the impacts of hazardous waste management activities. In the achievement of this overall goal, section 3004 authorizes the use of both the typical performance standard and the more specific design standard in setting detailed facility requirements. EPA has used both types of standards in regulations on the operating methods, techniques, and practices, and the location, design, and construction of hazardous waste facilities.

Regulated Facilities

Facilities must be operated and permitted according to the standards established by EPA under section 3004. EPA regulations have defined "treatment," "storage," and "disposal" quite broadly for the purposes of identifying activities that are subject to regulation.

A hazardous waste **treatment** facility is an operation that uses: "any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such wastes, or so as to recover energy or material resources from the waste, or so as to render such waste nonhazardous, or less hazardous; safer to transport, store or dispose of; or amenable for recovery, amenable for storage, or reduced in volume."[27] This definition of treatment is broad and includes such activities as dewatering or neutralizing hazardous waste, or mixing a nonlisted hazardous waste with a solid waste to render the resulting mixture nonhazardous. Recycling facilities are clearly within this definition, however, EPA has given them a broad exemption from most facility standards. The cleanup of an accidental spill of hazardous material may also fall within the definition of treatment and thus trigger the regulatory requirements.

A hazardous waste **storage facility** is any facility that is used for: "the holding of hazardous waste for a **temporary** period, at the end of which the hazardous waste is treated, disposed of, or stored elsewhere."[28] EPA rules provide that generators may store hazardous waste onsite for up to 90 days, and transporters may hold hazardous waste for up to 10 days, without becoming subject to the storage facility standards and permit requirements.

A facility operator is engaged in **disposal** activities under EPA rules if he engages in:

> . . . the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including groundwaters.[29]

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[27] 40 CFR 260.10 (1982).
[28] 40 CFR 260.10 (1982).
[29] 40 CFR 260.10 (1982).

However, EPA defines a hazardous waste **disposal facility** more narrowly as: "a facility or part of a facility at which hazardous waste is intentionally placed into or on any land or water, and at which waste will remain after closure."[30] The distinction between disposal as an activity and disposal facilities is made to allow EPA to maintain jurisdiction over an unintentional spill or other similar act that might occur, without necessarily requiring a facility permit based simply on the possibility of such an occurrence. The key to being a disposal facility therefore is that the waste is placed in the land or water so that it may enter the environment **and** that waste remains at the facility after closure.

Standards for TSDFs

EPA's implementation of requirements of section 3004 to establish performance standards for hazardous waste TSDFs has been a process characterized by delay, false starts, frequent policy reversals, and litigation.[31] One result of the complexity and delay encountered in developing a comprehensive regulatory system for hazardous waste is that EPA has promulgated three different sets of standards for TSDFs.

Interim Status Standards (40 CFR part 265).—These regulations, originally published on May 19, 1980, establish administrative and nontechnical facility standards applicable to all existing facilities operating under interim status and to special technical standards for different types of facilities. Existing facilities will continue operating under these requirements until a final facility permit is issued or denied.

General Status Standards (40 CFR part 264) (Permanent Program Standards).—Regulations establishing these final technical standards for **permitted** hazardous waste facilities were published over a 2-year period. These standards are applicable to new and existing facilities at the time the facility permit is issued. They generally impose more stringent detailed requirements that are adapted to the individual facility conditions and that are specified in the permit after the permit review.

Interim Standards for New Facilities (40 CFR part 267).—Because RCRA requires that issuance of a permit before the construction and operation of new hazardous waste facilities, the delays encountered in establishing final permitting standards threatened to stop construction of additional waste treatment and disposal capacity and the development of new, safer waste management technologies. EPA issued a set of temporary interim standards for permitting new facilities in January 1981 to remedy this situation. (A new facility is any facility that does not qualify as an existing "interim status" facility.) These interim standards were superseded as part 264 final permit standards became effective.

Interim Status Standards (ISS)

RCRA originally provided that no hazardous waste facility could operate without a permit beyond 24 months after the passage of the act (the date on which the original facility standards would have become effective if they had been issued on time). Section 3005 provided that an existing facility could apply for interim status allowing it to operate as if permitted, pending issuance of the standards and action on the permit application. The 1980 RCRA amendments changed the date on which facilities had to be in existence in order to qualify for interim status to November 19, 1980 (the effective date of the May 1980 implementing regulations).[32]

On May 19, 1980, EPA issued its initial hazardous waste regulations. This rulemaking included general administrative and nontechnical standards applicable for all TSDFs and more specific technical standards for different types of facilities. Table 54 summarizes the general interim status requirements applicable to most facilities.

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[30] 40 CFR 260.10 (1982).

[31] This history is detailed in the preamble to the final land disposal facility regulations issued in July 1982. See 47 F.R. 32,276-32,278, July 26, 1982.

[32] Solid Waste Disposal Act Amendments of 1980, Public Law 96-482, sec. 10, 94 Stat. 2338, Oct. 21, 1980.

Table 54.—Interim Status Standards: General Administrative and Nontechnical Standards for Interim Status Facilities

General requirements for all interim status facilities:

- Notify EPA of hazardous waste activities.
- Obtain EPA identification number.
- Submit Part A permit application.
- File annual or other periodic reports required by EPA.
- Comply with manifest system:
  - —Sign for receipt of waste shipment and return manifest copies to transporter and generator;
  - —Inspect shipment and report to EPA any significant discrepancies in amount, type of waste;
  - —Report unmanifested waste (except shipments from exempted small generators); and
  - —Maintain manifest copy at facility for 3 years.
- Notify EPA before receiving waste shipments from outside the United States.
- Notify new owner in writing of duty to comply with RCRA regulations.
- Maintain facility operating record over life of facility covering:
  - —Type, quantities, and location of each waste at facility;
  - —Method of treatment, storage, and disposal;
  - —Waste monitoring, testing, inspection results, and analytical data (maintain monitoring data for disposal facilities through post-closure period);
  - —Accidents requiring action under contingency plan; and
  - —Closure cost estimate (and post-closure costs estimate for disposal facilities).
- Waste analysis:
  - —Prepare and follow written waste analysis plan specifying detailed chemical and physical analyses to be conducted, sampling methods, and special analyses for ignitable, reactive or incompatible wastes, and for inspecting shipments for compliance with manifest;
  - —Test a representative sample of wastes before treatment, storage, or disposal; retest if change in waste generating processes or if offsite wastes do not match manifest description; and
  - —Maintain record of waste analyses results.
- Inspections and monitoring:
  - —Prepare and follow written operator's inspection schedule describing types of problems to be detected, and frequency of inspection;
  - —Inspect for spills at least daily; follow specific technology inspection and monitoring requirements under technical standards; and
  - —Maintain record of inspection results for 3 years.
- Ground water monitoring (landfills, surface impoundments, and land treatment facilities only):
  - —By Nov. 19, 1981, develop and implement ground water monitoring program for assessing the effects of the facility on the uppermost aquifer underlying the facility. Program must include:
    - (i) written ground water monitoring plan, including sampling and analysis specifications and methods;
    - (ii) installed system of ground water monitoring wells (at least one upgradient well and 3 downgradient wells); and
    - (iii) outline of ground water quality assessment program to be implemented if contamination is detected.
- Conduct sampling and testing of ground water:
  - —First year: quarterly samples of all monitoring wells to establish background levels of specified parameters:
    - (i) Maximum contaminant levels in National Interim Primary Drinking Water Standards (21);
    - (ii) Water quality indicator parameters: chloride, iron, manganese, phenols, sodium, and sulfate; and
    - (iii) Ground water contamination indicator parameters: pH, specific conductance, total organic carbon, and total organic halogen.
  - —Subsequent years: Test for each well quarterly for 6 background water quality indicator parameters; semiannually for 4 contamination indicator parameters.
- Continue monitoring program for life of facility and during 30-year post-closure period for disposal facilities.
- Report ground water monitoring results (for landfills, surface impoundments, and land treatment facilities):
  - —Waivers of ground water monitoring program available: (i) by demonstrating low potential for migration of waste constituents from facility via uppermost aquifer to water-supply wells. (Written determination is made by facility operator and certified by qualified geologist or geotechnical engineer.) and (ii) for surface impoundments neutralizing corrosive waste if demonstrate no potential for migration from impoundment.
  - —Use of alternative ground water monitoring program similar to ground water assessment program allowed if monitoring of indicator parameters would show statistically significant changes in water quality.
- Handling ignitable, reactive, and incompatible wastes—waste analysis and special safety precautions such as waste segregation, smoking restrictions, and limits on mixing these special wastes are required.
- Site security:
  - —Maintain site security to prevent unknowing entry, and to minimize unauthorized entry into facility through 24-hour surveillance, barriers, fencing, posted warnings; and
  - —Control entry to active portion of facility.
- Personnel training:
  - —Assure that facility personnel are trained in waste management, operating, and emergency procedures; and
  - —Maintain personnel training records until closure.
- Emergency preparedness and prevention and contingency plan:
  - —Provide internal alarm and emergency communications system, fire, spill control, and decontamination equipment, and device for summoning local emergency assistance;
  - —Test and maintain systems and equipment for emergency readiness;
  - —Develop written contingency plan for accidents and emergencies;
  - —Designate emergency coordinator; and
  - —Provide written report to Regional Administrator within 15 days of events requiring implementation of contingency plan.
- Closure:
  - —Develop written closure plan by May 19, 1981, including: methods of closing (or partially closing) facility at any time during life of facility and at end of operating life, estimate of largest inventory of waste in storage or treatment during life of facility, how facility and equipment will be decontaminated; estimated date of closure; estimated closure costs; and schedule for final closure;
  - —Notify EPA 180 days before closure begins;
  - —Submit closure plan within 15 days of loss of interim status or receipt of order to stop receiving waste;
  - —Follow closure plan;
  - —Complete all treatment, storage disposal activities within 90 days after receiving last waste shipment; and
  - —Complete closure within 180 days of beginning of closure period (unless date is extended by RA).

Table 54.—Interim Status Standards: General Administrative and Nontechnical Standards for Interim Status Facilities—Continued

- Obtain engineer's and operator's certification that closure is completed according to plan and all equipment and facilities have been decontaminated or disposed of accordingly.
- Post-closure (disposal facilities only):
  - —Develop written post-closure plan by May 19, 1981, specifying monitoring and planned maintenance activities to be carried on during 30-year post-closure period and identifying responsible person;
  - —Follow ground water monitoring plan and reporting requirements;
  - —File survey plat showing location, type and quantity of waste in disposal facility after closure, and amend title records showing use of land for waste disposal and restrictions on future use.
- Financial responsibility:
  - —Maintain on file at facility: (i) written estimate of closure costs, adjusted at least annually for inflation, and (ii) demonstration of mechanism facility will use to guarantee coverage of closure costs.
- Liability insurance:
  - —Maintain liability insurance or self-insurance for at least $1 million dollar per occurrence for sudden accidental injuries to persons or property from facility operations up to annual aggregate of $2 million (exclusive of legal costs);
  - —Owners of surface impoundments, landfills, and land treatment facilities must provide insurance or self-insurance of at least $3 million per occurrence for non-sudden accidental occurences up to an annual aggregate of $6 million (exclusive of legal costs). (Variations may be approved by RA for State insurance requirements or for State assumption of liability.)

SOURCE: 40 CFR Part 265.

The interim status standards have generally been characterized as "good housekeeping" requirements. Except for the ground water monitoring, closure, and post-closure care for disposal facilities, the interim status standards were intended by EPA to be "capable of being interpreted and applied in a straightforward manner without substantial expenditures by September 19, 1980.[33] (As explained later in this chapter, EPA's analysis of the ground water monitoring, closure, and post-closure requirements indicated that these imposed the major economic impacts of the interim status standards. However, of these, only ground water monitoring requirements imposed significant immediate expenses, and these were tempered somewhat by economies of scale enjoyed by larger facilities.)

Another significant feature of the interim status standards is that they are largely self-executing. That is, the facility owner or operator is responsible for being aware of, interpreting, and assuring compliance with the regulations. EPA and the States will conduct periodic inspections to determine if a facility is in compliance. Adhering to the interim status standards will not insulate a facility from having to comply with administrative orders or being subject to an imminent hazard action or other enforcement measure if the operation of the facility poses a threat to human health or the environment.

Interim Status Ground Water Monitoring Requirements

Any interim status landfill, surface impoundment, or land treatment facility must have a ground water monitoring program to assess the effects of the facility on the uppermost aquifer underlying the facility. The facility program must be in place by November 19, 1981. The program must be continued throughout the life of the facility and during the post-closure period for disposal facilities.[34] The ISS ground water monitoring program consists of three parts:

1. a written ground water monitoring plan (including sampling and analysis plan),
2. an installed system of ground water monitoring wells, and
3. a written outline of a ground water quality assessment program to be implemented if contamination is suggested by analysis of monitoring data.

The ISS ground water monitoring system must include at least one upgradient well to monitor background water quality and at least three downgradient wells sufficient to detect immediately any migration of a statistically significant amount of waste from the facility to the uppermost aquifer. The location, depth, and number of wells must be sufficient to yield representative measures of background water quality and to detect contamination.

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[33] 45 F.R. 33,159-60.

[34] See 40 CFR 265.90, 45 F.R. 33,239, May 19, 1980 and 47 F.R. 1254, Jan. 11, 1982.

Initial background levels for all monitoring wells must be established by sampling at least quarterly in the first year. The operator must test each well quarterly during the first year for 31 specified parameters. These parameters include the maximum contaminant levels established in the National Interim Primary Drinking Water Standards under the Safe Drinking Water Act regulations[33], ground water quality indicator parameters* and four ground water contamination indicator parameters.** These results are to be reported to EPA. After the first year, the operator must test quarterly for the six background water quality parameters and semiannually for the four parameters that indicate possible leakage.

By November 19, 1981, ISS facilities must prepare a written outline of a ground water quality assessment program to be implemented if monitoring indicated a statistically significant change in ground water quality. The assessment program must be designed to determine whether waste constituents have entered ground water, the extent of any contamination, the rate and extent of migration, and the concentration of the contaminant.

Within 7 days of obtaining results indicating significant changes in ground water, the facility must notify the Regional Administrator. Within an additional 15 days, the facility must submit its ground water quality assessment plan based on its previously prepared written outline and implement the plan. Additional reports based on the assessment plan must also be submitted to the EPA Regional Administrator. The facility must continue to monitor under the assessment program at least quarterly until closure. **Unlike the standards for permitting land disposal facilities, the interim status standards do not require implementation of corrective action, only continued monitoring of the contamination.** However, EPA may accelerate the call up of the facility's part B permit application, or initiate imminent hazard action or a section 3013 administrative order after receiving notice that the facility may be affecting ground water quality.

All or part of the ground water monitoring requirements can be waived under certain circumstances. If, based on evaluation of certain specified site conditions, the operator demonstrates that "there is a low potential for migration of hazardous waste constituents from the facility via the uppermost aquifer to water supply wells," the facility need not implement a ground water monitoring program. This demonstration must be in writing, certified by a qualified geologist or "geotechnical" engineer, and maintained at the facility.

The ground water monitoring requirements may be waived for surface impoundments that are used only to neutralize corrosive wastes if the operator demonstrates that there is no potential for the migration of hazardous wastes from the impoundment. This determination must be in writing, and certified by a qualified professional.

These waivers of the ground water monitoring standard are made by the facility operator and are not reported to EPA or the State. However, the determinations must be maintained in the facility file and will be reviewed during compliance inspections and permit review by EPA or the State agency. If this review indicates that the waiver was unwarranted, the facility is subject to penalties for violation of RCRA regulations.

The facility may implement an alternative ground water monitoring system other than the one specified in the regulations if the required ground water indicator parameters would show statistically significant changes in water quality. The alternative ground water monitoring plan must be submitted to the Regional Administrator and certified by a qualified geologist or geotechnical engineer.

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[33] See 40 CFR Part 265, App. III (1982).

*Chloride, iron, manganese, phenols, sodium, sulfate.

**Specific conductance, pH, total organic carbon, and total organic halogen.

ISS Closure and Post-Closure Requirements

Interim status facilities that close before a permit is issued must comply with ISS closure and post-closure requirements. These standards are similar to the permanent program standards, except that they do not require more extensive corrective action and ground water monitoring requirements for land disposal facilities. Closure is a period after which hazardous waste is no longer accepted at facility, all treatment, storage, and disposal operations are completed, and the facility is closed by, for example, installing the final cover on a landfill or draining and cleaning storage tanks. The closure period generally will last 6 months. Post-closure is the 30-year period after closure when operators of disposal facilities must perform monitoring and maintenance activities.

The purpose of the ISS closure regulations is to ensure that facilities are closed properly: 1) to minimize need for further maintenance, and 2) to control, minimize, or eliminate post-closure escapes of hazardous waste or constituents into the environment.

There are specific requirements for different technologies as well as general requirements. Under general requirements, by May 19, 1981, all TSDF operators were to have prepared a written closure plan to be maintained on file at the facility and identify the steps necessary to completely or partially close the facility **at any point** during its intended operation and at the end of its operating life.[38] The plan also must include estimates of the largest inventory of waste that will be in storage or treatment during facility life, the anticipated closure date, and an estimate of closure costs. The operator must amend the plan to reflect changes in the TSDF operations affecting the closure plan or planned closing date. The plan must be available to EPA on request and at inspection.

When an operator decides to close a facility, the plan must be submitted to the EPA Regional Administrator 180 days before closure begins (comments and hearings may be required). (If an operation loses interim status or is ordered to stop receiving waste, it must submit a closure plan to EPA in 15 days.)

Closure begins when the last shipment of hazardous waste is received, the operator then has 90 days to complete all treatment, storage, and disposal activities or to remove waste from the site. All closure activities must be completed within 6 months or 180 days. This time can be extended by the EPA Regional Administrator for certain conditions. Finally, the operator and a professional engineer must certify that the facility has been closed in accordance with an approved plan and that all equipment and structures have been disposed of or decontaminated.

Post-Closure Plan

By May 19, 1981, all disposal facility operators must also have a written post-closure plan identifying the activities to be carried on for 30 years after closure. The plan must at a minimum include provisions for ground water monitoring and reporting, the planned maintenance activities to ensure the integrity of the final cover or containment and the functioning of monitoring equipment; and the identity of the persons to be contacted about the facility during post-closure.

Within 90 days after closure, the operator must provide the Regional Administrator and local land use authorities with a professional survey plan showing the disposal areas, types, location, and quantities of the disposed waste. The owner must amend the deed or title records to note that the land was used for hazardous waste disposal and that its future use is restricted.

ISS Financial Responsibility and Insurance Standards

The ISS financial responsibility requirements apply to all TSDFs except those operated by Federal or State Governments. They were imposed to assure that funds will be available to pay for closure and post-closure care and to compensate third parties for any injuries suffered as a result of facility activities. The interim status financial responsibility and liability insurance standards are nearly identical to the standards for permitted facilities.

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[38] 40 CFR 265, subpart G (1982).

Each facility must have on file a written estimate of closure costs (to be adjusted annually to reflect inflation) demonstrating how the facility plans to cover its closure costs. One or a combination of several mechanisms can be used to meet closure costs, including:

- a trust fund,
- a surety bond guaranteeing payment into a trust fund,
- an irrevocable letter of credit,
- a financial assets test, or
- an insurance policy.

The same mechanisms can be used to demonstrate financial responsibility for post-closure care. For permitted facilities, the rules allow the posting of a surety bond guaranteeing the performance of the closure plan as an additional means of demonstrating financial responsibility. The interim status standards also impose liability insurance requirements for hazardous waste TSDFs. The facility owner or operator must maintain liability insurance or self-insurance of at least $1 million per occurrence with an annual aggregate of $2 million for claims of sudden accidental injuries to persons or property from facility operations (exclusive of legal costs). Owners or operators of surface impoundments, landfills, and land treatment facilities must carry additional insurance of at least $3 million per occurrence and $6 million annual aggregate (excluding legal fees) for nonsudden accidental occurrences. These nonsudden liability requirements will be phased in over 3 years beginning January 1983 for owners who obtain an optional policy for both sudden and nonsudden occurrences that provide coverage of at least $4 million per occurrence and $8 million annual aggregate (exclusive of legal fees).[37]

Variations in these requirements are allowed to provide for use of State insurance requirements in States where Federal program requirements apply if the coverage is consistent and includes at least the same amount of funds and coverage. If a State assumes the responsibility for closure, post-closure care, or liability coverage at a facility (an aspect of some State siting programs), this assumption may be approved by the Regional Administrator as an alternative to liability insurance.

Interim Status Standards for Landfills

Interim status landfills are subject to the general facility standards, some additional technical standards for ground water monitoring, financial responsibility, and closure and post-closure care. Basically, the interim standards are directed at controlling the general problems associated with landfill operations: fire, explosion, toxic fumes, and contamination of surface and ground waters. The facility must be operated to divert rainwater run-on into, and to collect runoff from, the active portion of the landfill. Measures to control wind dispersion of contaminated soils must be adopted (if necessary). Ignitable and reactive wastes must be treated or mixed before landfilling so that they no longer meet ignitable or reactive waste characteristics.

Specific requirements are imposed to limit the **disposal of liquids in landfills** that could form leachate that would allow waste constituents to enter the environment. The May 1980 rules banned most landfilling of free liquids or wastes containing free liquids after November 19, 1981. An exception was made for disposal of bulk liquids or noncontainerized liquids in a landfill with a liner that is chemically and physically resistant to the liquid and with a leachate collection and removal system to remove any leachate. The rules also allowed landfilling of liquids in very small containers (e.g., capsules) and in containers (e.g., batteries) that were not designed for the purpose of storage.

Among the exceptions to the original restrictions on disposal of liquids in landfill are the following:

- containerized liquid ignitable wastes until May 26, 1982, if they were protected from

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[37] See 40 CFR 265.147 (1982).

materials or conditions that would cause them to ignite;[38]
- labpacks (overpacked metal drums holding smaller nonleaking containers of hazardous waste and absorbent material to absorb any leaks) as long as certain restrictions on ignitable, reactive, and incompatible wastes are met;[39]
- liquid containerized waste that is treated or stabilized so that free liquids are no longer present (e.g., absorbent material is added to the drum); and
- containers holding free liquids if the liquids are removed from the container or absorbent material is added before landfilling so that free liquids do not remain.

The July 1982 land disposal regulations modified the interim status standards applicable to landfills to make them consistent and conforming with final technical standards for permitting. Further provisions were added to landfilling of containerized liquid waste to reduce the likelihood of subsidence and leading by requiring the filling of a container with 90-percent absorbent solid material or crushing, shredding, or "similarly reducing" the container in volume before landfilling.

The function and design of the final landfill cover must be specified in the closure and postclosure plans. Also, the plan must include strategies to: control surface water infiltration and migration of pollutants from the facility and prevent erosion; maintain the final cover; monitor leachate and gas control systems; maintain and protect surveying benchmarks; and restrict access to the facility.

Interim Status Standards for Incinerators

The interim status standards for incinerators impose general operating requirements aimed at reducing the potential hazards involved. No special technical performance or design standards were imposed. Additional analysis of the wastes to be incinerated is required to determine their heating value, halogen content, sulfur content, and concentrations of lead and mercury. The incinerator must be operating at steady state conditions before waste is added. The existing combustion and emission control instruments must be checked every 15 minutes. Outside stack gases must be visually inspected every hour, and the incinerator and associated equipment must be inspected daily. At closure, all wastes and residues must be removed from the facility. Hazardous waste residues must be sent to an approved facility. (Note: many incinerators also qualify as treatment and storage facilities because they accumulate or treat wastes before incineration and must comply with those standards as well.)

EPA has made two significant exemptions to the interim status standards for incinerators. Boilers that burn hazardous waste to recover energy are currently excluded from the definition of disposal by incineration and are not subject to any standards under Subtitle C of RCRA. A limited exemption from interim status standards is granted to incinerators that burn waste that is considered hazardous solely because it is corrosive or ignitable, or both, or waste that is listed because it possesses certain reactivity characteristics (described in 40 CFR 261.23 (a)(1),(2),(3),(6),(7), or (8)) and will not be burned when other hazardous wastes are present in the combustion zone.

The subpart O standards for additional waste analysis, monitoring, and inspection are not required of these incinerators if the operator demonstrates in writing that such ignitable, corrosive, or reactive waste would not reasonably be expected to contain any of the Appendix VIII toxic constituents. The written demonstration must be maintained at the facility and will be reviewed when the facility is permitted. These special incinerators, however, must comply with the general facility interim status standards including reporting, recordkeeping, initial waste analysis, facility operation and inspection, compliance with the manifest system and financial responsibility, and compliance with the special standards for incinerator closure.

The interim status standards for incinerators were amended in January 1981 and June 1982 to make them conform with changes adopted for permanent program permitting standards.

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[38] 47 F.R. 8,307, Feb. 25, 1982, 40 CFR 265.312 (b).

[39] 46 F.R. 56,592, Nov. 17, 1981, 40 CFR 265.316.

Interim Status Standards for Surface Impoundments

Regulations imposing operating requirements for existing surface impoundments used for storage, treatment, or disposal of hazardous wastes are intended to minimize or control the major problems encountered with these facilities—leakage of hazardous waste constituents to ground water, air emissions from volatile wastes, and overtopping of the impoundments and spilling of the wastes because of overfilling, precipitation, run-on, or wind.

The standards require that surface impoundments be operated to maintain at least 2 ft of freeboard[88] to protect against overtopping. Impoundments with earthen dikes must have protective covering such as grass, rocks, or plastic sheeting to limit erosion and maintain structural integrity. Additional waste analyses are required before use of the impoundment for new wastes or use of new treatment processes. Ignitable or reactive wastes must be pretreated to remove the hazardous characteristics before being placed in a surface impoundment. Incompatible wastes must not be put in surface impoundments. The level of freeboard in an impoundment must be inspected daily to detect or prevent overtopping, and the structure and associated equipment must be inspected weekly for leaks or deterioration. Surface impoundments must comply with the ground water monitoring regulations for interim status facilities.

At closure, all wastes, residues, and contaminated soils must be removed from the facility and sent to an approved treatment or storage facility. If the surface impoundment is a disposal facility, it must follow final closure procedures similar to those for landfills, meet financial responsibility requirements, and provide post-closure care.

General Facility Standards for Permitting Hazardous Waste TSDFs

The interim status standards govern facility operation until a permit is issued. Before a facility is issued a final permit, it undergoes a detailed review to determine that its future generation will be in compliance with the general Phase II standards.

More than 10,000 existing facilities submitted part A permit applications to obtain interim status. Most of these facilities will have to be permitted under the final standards. This process is expected to take 5 years or more. EPA anticipates that a significant number of smaller interim status landfills and surface impoundments will close rather than incur the expenses of upgrading the facility to obtain a permit.

Table 55 summarizes some of the key elements of EPA's final part 264 permit standards. These standards incorporate and build on the interim status requirements. For example, ground water monitoring at landfills during interim status will indicate if any contamination may have occurred and thus be used to decide what type of monitoring and corrective action may be demanded as a permit condition if the facility continues to operate (see table 56).

A major criticism of the adequacy of interim status requirements has been that they will govern TSDF operations until a permit is issued—which could be 5 years. Neither the interim status standards nor the permit standards have addressed whether more stringent standards for inspection, prepermit reviews, and monitoring are necessary to identify and correct situations that may pose a threat to human health and the environment before the ISS facility is called in for its permit review.

The permanent program standards of 40 CFR part 264 are largely identical to the interim status requirements for waste analysis, personnel training, emergency prevention and preparedness, contingency planning, closure and

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[88] 40 CFR 265.222 (1982).

Table 55.—Technical Performance Standards for Containers, Tanks, Incinerators, Landfills, and Surface Impoundments

Design and operating conditions	Inspection and monitoring	Closure/post closure
Containers (Subpart I)		
Container and/or liners must be compatible with wastes. Storage area containment system must control the larger of 10 percent of the volume of the wastes or the volume of largest container. Storage area must have impervious base, run-on controls, and collection system designed for control of and removal of liquids, spills, and run-on unless containers are elevated or protected from contact with liquids. No spill containment system required for wastes that do not include free liquids if the storage area is designed so that liquids cannot come in contact with containers. Containers must be closed except when adding or removing wastes.	Weekly inspections of containers, storage areas, and containment systems for leaks, spills, or deterioration.	Remove all wastes, residues, decontaminate containers; send hazardous wastes to TSDF.
Tanks (Subpart J)		
Applicable to all treatment and storage tanks, except covered underground tanks that cannot be entered for inspection. Tank must have sufficient shell strength to prevent rupture or collapse; minimum shell thickness to be specified by RA in permit. Tanks and/or liner must be compatible with wastes. All tanks must have controls to prevent overfilling. Covered tanks must have pressure controls. Uncovered tanks must have controls for preventing run-on and maintain sufficient freeboard to prevent overflow as specified by RA in permit. Special contingency plan for spills or leaks must provide for expeditious waste removal and repair of tanks.	Check overfilling controls and any monitoring equipment daily. Check liquid level of open tanks daily. Weekly inspection of aboveground construction and surrounding areas for corrosion or leaks. Schedule for emptying of tank and entry for inspection of interior to be specified in permit.	Remove wastes, residues, decontaminate tanks and equipment. Send hazardous waste to TSDF.
Incinerators (Subpart O)		
Incinerators must achieve: 99.99 percent destruction removal efficiency (DRE) for principal organic hazardous constituents (POHCs) specified in permit and specific emissions limits for HCl and particulates set in permit. Facility must install monitoring equipment and process controls necessary to assure operation within permit limits at all times, to control fugitive emissions, and to provide automatic waste feed shutoff if operations exceed permit conditions. Permit will specify acceptable range in composition and operating limits for each waste feed. Facility must burn only waste feeds approved in permit under specified operating conditions based on trial burn or alternative data. *Exemptions:* Facilities burning only ignitable, corrosive, or reactive wastes that contain no, or insignificant amounts of, Appendix VIII constituents and that will not pose a threat to human health or the environment if incinerated can receive a limited exemption. These facilities must be permitted and comply with Subpart O waste analysis and closure standards and with general Part 264 TSDF standards.	A. Submit trial burn emissions monitoring results for different waste feeds for permit. Special trial burn permit for new facilities required. B. During operation: daily visual inspection of incinerator and equipment for spills, leaks, fugitive emissions; continuous monitoring of temperature, feed rate, air flow, stack gas CO, and other indicators of operating conditions and possible malfunctions. At RA request, sample and analyze waste feeds and stack gas emissions to verify compliance with standard. Weekly test of waste feed cutoff system and alarms unless RA specifies less frequent period.	Remove wastes and residues, decontaminate equipment; send hazardous wastes to TSDF.

Table 55.—Technical Performance Standards for Containers, Tanks, Incinerators, Landfills, and Surface Impoundments—Continued

Design and operating conditions	Inspection and monitoring	Closure/post closure
Landfills (Subpart N)		
All landfills (except existing portions) must have a *liner* to prevent migration of wastes to soils, ground, or surface waters through closure. Material must prevent waste passing into liner during active life of unit, resist failure and degradation, and be compatible with wastes. Liner must cover all earth likely to be in contact with wastes or leachate. Liner base must support and resist pressure gradients to prevent failure. RA will set liner design and operating specifications to achieve performance standards in permit. All landfills (except existing portions) must have a *leachate collection and removal system* above the liner designed and operated to prevent liquids accumulation of more than 1 ft above the liner and to function without failure, clogging, or degradation through scheduled closure. RA will set design and operating specifications for leachate collection system in permit. *Exemptions* from liner-leachate collection system requirements can be granted by RA if alternative design and operating practices and locations prevent migration of *any* hazardous constituent to ground or surface waters at *any* time in the future. All landfills must install run-on controls and runoff management systems sufficient to control flow into or out of the unit from a 24-hr 25-yr storm and control wind dispersal of particulates. Disposal of bulk liquids in landfills is limited to facilities with liners and leachate collection and removal systems. Design and operating conditions necessary to achieve performance standards will be specified in the permit by RA.	Inspect liner, leachate collection system and cover, during and after construction or installation for defects, damage, or nonuniformities that may affect performance. Inspect weekly for improper operation, deterioration, malfunction of run-on or runoff, and wind dispersal controls, and for liquids in leak-detection system or leachate in the leachate collection system and proper functioning of systems. All "regulated" units must implement ground water monitoring program as specified in permit. *Exemption from detection monitoring program* for facilities that install double liners with leak-detection system between the liners. If any liquid is detected between liners, facility must repair the liner or lose the exemption. *Exemption from ground water monitoring* may be granted if RA finds that there is *no potential* for migration of liquid from a regulated unit to the uppermost aquifer during the active life and closure and post-closure care periods.	Final cover should minimize liquid migration through closed unit, require minimal maintenance, promote drainage, resist erosion or abrasion of cover, accommodate settling, subsidence while assuring cover integrity. Cover permeability should be less than or equal to the liner or natural subsoils. Facility must comply with permit specifications on closure and post-closure care for maintenance of final cover, monitoring, and leak-detection systems. Leachate collection system must be operated until leachate is no longer detected. Ground water monitoring and response program requirements must be observed.
Surface Impoundments (Subpart K)		
All surface impoundments (except existing portions) must have a liner that prevents migration of any wastes out of the impoundment to adjacent soil, or surface or ground water at any time during the active life of the facility (including closure). *Exemption* from liner requirement for alternative design and operating practices and location characteristics that prevent migration of *any* hazardous constituent into ground or surface water at any future time. Impoundment must be designed, built, and operated to prevent overtopping from overfilling, run-on, malfunction, or human error. Dikes and containments must be designed, built, and maintained to prevent massive failure without relying on the assumption that the liner will function without leakage during the active life of the unit. Special contingency plan provisions for immediate shut down, spill containment, emptying of unit, and emergency repairs. The RA will specify all design and operating requirements necessary to meet these standards in the permit.	Inspect liner and cover during and after installation for defects, damage, or nonuniformities that may affect performance. At least weekly and after storms, inspect for evidence of deterioration, malfunction, improper operation of overtopping controls, drops in level of contents, liquids in the leak-detection system, severe erosion, or deterioration in dikes or other containments. Implement appropriate ground water monitoring program specified in permit unless an exemption applies (see landfills).	Remove all wastes and residues, decontaminate equipment at storage impoundments; send wastes to TSDF. At disposal impoundments: eliminate free liquids and/or solidify wastes and residues to stabilize waste to support final cover. Final cover should minimize liquid migration through unit, require minimal upkeep, promote drainage, resist erosion and abrasion of cover, and accommodate settling and subsidence while maintaining cover integrity. Cover permeability should be less than or equal to liner or natural subsoils. Observe closure and post-closure care, maintenance, inspection, and monitoring of cover, run-on, runoff controls, ground water monitoring system, and leak-detection system. If leak-detection system indicates presence of liquid, notify RA for permit modification for appropriate ground water monitoring program under Subpart F. Ground water monitoring and response program requirements must be observed.

NOTE: RA—Regional Administrator.

SOURCE: 40 CFR Part 264.

Table 56.—Ground Water Monitoring Program for Permitted Land Disposal Facilities

All "*regulated units*"—new or existing land disposal units that receive wastes after Jan. 26, 1983—must install a ground water monitoring system at the compliance point and implement the monitoring and response program specified in permit.

Exemptions from the ground water protection program can be granted for facilities where there is *no potential* for migration of *liquid* from the regulated unit to the uppermost aquifer during the active life through the post-closure care period.

Detection monitoring program*—To be implemented by facilities where there is no indication of leakage when permit is issued and to be continued during the active life of the unit through the post-closure period.*

Facility owner/operator must:

- Sample each monitoring well at least semiannually for the indicator parameters, waste constituents, or reaction products specified in the permit; and
- Determine ground water flow rate and direction in the uppermost aquifer at least annually.

If detection monitoring results indicate a statistically significant increase over background values of ground water concentrations of any specified parameter at any well at the compliance point, the owner/operator must notify the RA and:

- Immediately sample ground water at all monitoring wells to determine the concentration of all Appendix VIII constituents that are present in ground water and establish a background value for each Appendix VIII constituent at the compliance point;
- Submit a permit modification application for a compliance monitoring program (including a proposed concentration limit for each hazardous constituent found at the compliance point) *or*, alternatively, demonstrate that the statistically significant increase is caused by a source other than a regulated unit, or results from an error in sampling, analysis, or evaluation.

Exemption from detection monitoring program is provided for double-lined facilities with leak detection system between the liners and which are located above the seasonal high water table. If liquid is detected between the liners, the liner must be repaired and certified to maintain the exemption.

Compliance monitoring program*—To be implemented whenever hazardous constituents are detected at the compliance point and to be carried out during a specified compliance period.*

The owner/operator must track the migration and concentration of hazardous constituents from the regulated unit to determine if the units are in compliance with the ground water protection standard specified in the permit consisting of:

- A list of the hazardous constituents to be monitored; and
- A concentration limit for each hazardous constituent based on:
  (a) background level;
  (b) maximum concentration limits (MCLs) for 14 constituents under the SDWA regulations, if the MCL is higher than background level; or
  (c) an alternate concentration limit approved by the RA.

Under the compliance monitoring program, the owner/operator must:

- Measure the concentrations of specified hazardous constituents in ground water at each monitoring well at the compliance point at least quarterly;
- Determine the ground water flow rate and direction in the uppermost aquifer at least annually; and
- Sample all monitoring wells at least annually for Appendix VIII constituents to determine if additional constituents not identified in permit are present in ground water and report any additional constituents to the RA.

If monitoring results indicate that the ground water protection standard specified in the permit is being exceeded for any hazardous constituent at any monitoring well at the point of compliance, the facility owner/operator must notify the RA and:

- Submit a permit modification application for establishment of a corrective action program; or
- Demonstrate that the ground water protection standard is being exceeded because of an error in sampling, analysis, or evaluation or because of contamination from a source other than a regulated unit.

Corrective action program*—To be undertaken if compliance monitoring indicates that the ground water protection standard is exceeded and to be continued until the levels of hazardous constituents are reduced below their respective concentration limits.*

The corrective action program to be specified in the permit consists of:

1. Specific corrective measures to remove the hazardous waste constituents or to treat them in place to prevent levels of hazardous constituents exceeding the ground water protection standard at the compliance point; and
2. A monitoring program for determining the success of corrective actions and for measuring compliance with the ground water protection standard.

If concentrations of hazardous constituents in the ground water between the compliance point and the downgradient facility boundary exceed the ground water protection standard, the operator also must take corrective actions specified in the permit to remove or treat in place those hazardous constituents.

The owner operator must report annually on the effectiveness of the corrective action.

Corrective action measures may be terminated and the facility may resume compliance monitoring once the concentration of hazardous constituents is reduced to below the specified limits.

If the owner/operator is conducting corrective action at the end of the compliance period, the corrective action must be continued until monitoring data shows that the ground water protection standard has not been exceeded for a period of three consecutive years.

SOURCE: 40 CFR 264, Subpart F.

post-closure care, and financial responsibility (see table 54 and discussion of these provisions under interim status standards above). The permanent program standards do add some additional requirements—two location criteria for facilities in seismically active areas and in 100-year flood plains. The part 264 standards impose more detailed monitoring and inspection than the interim status standards. During permit review, the general standards of the regulations will be tailored to the specific conditions of each facility, and special operating stipulations will be incorporated into the permit by the Regional Administrator. EPA guidance documents will provide detailed instructions for interpreting and applying the part 264 standards and measuring the adequacy of each permit application.

Among the most important part 264 standards are the requirements for permitting new and existing incinerators and land disposal facilities (landfills, surface impoundments, waste piles, and land treatment units). EPA has adopted general performance standards for these facilities that will be converted into specific and detailed permit conditions by the permit writer based on consideration of information supplied with the part B permit application and EPA guidance materials. The general strategy of the part 264 permit standards are discussed below. Criticisms of the adequacy of these standards are addressed in part III of this chapter.

Storage Facilities

The standards applicable to surface storage facilities (tanks and containers)* and their related treatment operations focus on the containment of wastes to prevent their uncontrolled release into the environment. All storage facilities must have a primary containment system to hold the waste and to prevent spills and leaks. In order to detect cracks, corrosion, deterioration, and leaks, an inspection program is required, to the extent practical. Design specifications for the tanks will be reviewed by the Regional Administrator who will require a minimum shell thickness to be maintained. This design standard will be set on a case-by-case basis by the Regional Administrator applying appropriate industrial design standards.[41] Where primary containment devices are easily damaged or are impractical to inspect, a secondary containment system is also required. Standards for underground storage or treatment tanks have not been promulgated.

Incinerators

The Phase II regulations for incinerators include the "good operating practice" standards established for interim status facilities as well as additional performance and design requirements. Before an incinerator can receive a permit, it must conduct trial burns for the waste feeds that it proposes to incinerate. New facilities must obtain a trial burn permit granted for a limited duration following submission and approval by EPA of a detailed plan for the test burns. Permitted incinerators must meet three performance standards: 1) a minimum (99.99 percent) destruction and removal efficiency rate (DRE) for each principal organic hazardous constituent (POHC) designated by EPA for each hazardous waste feed; 2) a maximum emissions rate of 1.8 kg/hr or a minimum removal rate of 99 percent for hydrogen chloride from the exhaust gas emitted from incinerators burning hazardous waste containing more than 0.5 percent chlorine; and 3) a maximum emission rate of particulates of 180 milligrams per dry standard cubic meter.[42] In addition, incinerators must meet specified operating conditions, and provision must be made for continuous monitoring with respect to combustion temperature, waste feed rate, air feed rate, and carbon monoxide content of the exhaust. Daily inspections are required of incinerators and associated equipment, including alarm systems and emergency shutdown controls. Incinerators must upgrade and install necessary monitoring equipment and emissions controls. Limited exemptions for incinerators burning certain ignitable, corrosive, or reactive wastes can be generated if it is demonstrated that the waste either does not contain or contains very small concentrations of Appendix VIII hazardous constituents.

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*Note: the storage facility regulations issued in January 1981 originally included waste piles and surface storage impoundments—these provisions were superseded by the July 1982 and land disposal regulations.

[41] 40 CFR 264.191 (1982).

[42] 40 CFR 264.343 (1982).

Land Disposal Facilities

Promulgation of final standards for land disposal facilities (landfills, surface impoundments, waste piles, and land treatment units) was delayed owing to EPA's decision in February 1981 to repropose these standards in a form substantially revised from the approach originally proposed in December 1978. The emphasis was shifted from the setting of uniform design requirements to the use of more general performance standards. (The original design standard approach was subject to opportunities for variances when alternative designs could achieve equivalent environmental protection. These variances included use of risk assessment.) **The July 1982 performance standards rely on a site-specific approach allowing specific measures for the protection of ground water and the environment to be developed during the permitting process.** Final regulations governing land disposal facilities were promulgated on July 26, 1982, and became effective on January 26, 1983, 6 months later.[43] These regulations are discussed in part III of this chapter and summarized in tables 55 and 56.

Facility Permitting

Section 3006 of RCRA requires that owners and operators of hazardous waste TSDFs must obtain a permit. Permits are to be issued either by EPA under the Federal part 264 final technical standards and part 122 and 124 consolidated permit procedures or by a State under an authorized State hazardous waste program. Existing facilities that qualify for interim status may continue operating without a permit pending review of their applications. Interim status facilities are treated for purposes of RCRA as if a permit has been issued.

To qualify for interim status, a facility must: 1) have existed on November 19, 1980, 2) have notified EPA of its hazardous waste activities under section 3010, and 3) submitted its part A permit application. The interim status is valid as long as requirements continue to be met.

EPA has divided the permit application for hazardous waste facilities into two parts:

1. **Part A.**—The initial permit application, which includes information on the facility location, design capacity, types and quantities of hazardous waste handled, and proximity to drinking water wells, and which was in most cases to be submitted by November 19, 1980.
2. **Part B.**—The final permit application to be submitted to demonstrate compliance with the part 264 general facility standards, which includes more detailed technical information on facility design and operating procedures.

With the promulgation of technical standards for most TSDFs, it is now possible for EPA to process part B applications. However, existing facilities have been asked to wait until EPA requests them to submit their final applications. The agency expects it will take several years to complete the initial round of permit-granting activities. Applications for new facilities are being given a high priority since neither construction nor operation can begin without a permit.

Each part B permit application is first reviewed for completeness. If it is complete and indicates compliance with standards, a draft permit is prepared and made available for public notice and comment, and (if warranted) public hearings. The draft (and final) permit will contain the specific conditions applicable to each facility and may include additional requirements that the Regional Administrator may impose (e.g., as added liability insurance coverage, the specific indicator parameters to be included in a ground water monitoring program, or the wastes that may be burned at an incinerator). After considering the comments, EPA issues a final decision on the permit application responding to all significant comments. Appeals may be made within 30 days. State procedures may differ slightly, but all State procedures must include adequate opportunities for public participation.

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[43] 47 F.R. 32,274.

Final permits generally will be issued for a fixed term not exceeding 10 years. The facility operation will be reviewed at the end of the permit term, before renewing the permit. (A modification of the permit period from 10 years to the lifetime of the facility is under consideration by EPA.) A facility must operate under a permit throughout its active life and any post-closure period as well as during any compliance period required of the facility. The EPA Regional Administrator can review a permit at any time to determine whether it should be modified, revoked, reissued, or terminated.

EPA will grant RCRA permits-by-rule to certain hazardous waste facilities that are permitted under other Federal laws provided that they meet special RCRA conditions.[44] Eligible facilities include barges or vessels used for ocean disposal of hazardous waste (Marine Protection, Research, and Sanctuaries Act), underground injection wells (SDWA), and publicly operated treatment works (CWA).

To simplify the permit application and review process and to avoid duplicative requirements, EPA adopted the consolidated permit regulations. These provisions allow an applicant to submit information required for several different permits on a single standardized form. The rules also establish a uniform permit review and approval process applicable to all permit applications under the following programs:

- the Hazardous Waste Management Program under RCRA;
- the Underground Injection Control Program under SDWA;
- the National Pollutant Discharge Elimination System under CWA; and
- the Prevention of Significant Deterioration Program under CAA, where this program is operated by EPA.

Imminent Hazard and Enforcement Provisions

RCRA provides EPA with a variety of mechanisms to measure and enforce compliance with the Federal program requirements and to take necessary action to mitigate threats to human health and the environment from hazardous waste management activities.

Section 3007 of the act authorizes any EPA employee (or representative, such as a contractor) or an employee of a State with an approved program, to inspect at reasonable times the premises of any generator, transporter, or facility operator (including any person who was engaged in such activities in the past).[45] Access to records and property relating to hazardous waste is also required for inspection purposes. Failure to cooperate with an inspection may subject the party to enforcement penalties. This inspection authority is not limited to hazardous waste as defined in RCRA regulations, but may also be used whenever EPA has reason to believe that the material involved may be hazardous under the broad statutory definition. (Generators or facilities that are currently excluded or exempted from RCRA regulations are subject to EPA's inspection authority to determine if they are properly claiming such exclusion or if a hazard exists.)

Section 3013 is an important information-gathering tool added by the 1980 amendments.[46] Section 3013 of the act authorizes EPA to issue an administrative order requiring site monitoring, assessment, and reporting. If EPA believes that hazardous waste on the site may pose a substantial hazard to health or the environment, EPA may order the past or present owner or operator of an active or inactive hazardous waste facility to implement a monitoring and testing program. EPA has invoked this provision on several recent occasions for facilities that have violated hazardous waste rules possibly resulting in environmental contamination.

RCRA provides EPA with a range of administrative and judicial enforcement options

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[44] 40 CFR 122.26 (1982).

[45] 42 U.S.C. 6927.

[46] 42 U.S.C. 6934.

and civil and criminal penalties that may be used against persons who violate RCRA, its implementing regulations, or permit conditions. The civil enforcement options include issuance of administrative compliance orders requiring immediate action or action according to a specified schedule for correcting violations of subtitle C requirements. Alternatively, EPA may sue in Federal court for an injunction requiring correction of the violations. Noncompliance may result in permit suspension or revocation and/or imposition of civil penalties of $25,000 for every day of violation.[47]

RCRA imposes criminal sanctions for violation of administrative or judicial compliance orders. It is a Federal criminal offense for any person **knowingly:**

1. to transport a hazardous waste to an unpermitted facility;
2. to treat, store, or dispose of hazardous waste without a permit or in knowing violation of any material condition of a permit;
3. to make a false statement or representation in any application, label, manifest, report, record, or other document used in the RCRA program; or
4. to generate, store, treat, transport, dispose of or otherwise handle any hazardous wastes **and knowingly** to destroy, alter, or conceal any record required to be maintained under RCRA regulations.[48]

Conviction of these knowing violations can result in fines of up to $25,000 or $50,000 per day and imprisonment of up to two years. These penalties are more severe than the criminal sanctions imposed under, for example, CWA. Criminal proceedings may be brought against corporations or individuals. Individual employees of firms that violate RCRA hazardous waste regulations can be prosecuted, fined, and imprisoned for their part in the offense. The corporate shield does not insulate them from the consequences of their actions.

The 1980 amendments created an additional felony offense for particularly egregious violations which carry severe criminal penalties or fines of up to $250,000 for individuals or up to $1 million for corporations and/or imprisonment of up to 5 years.[49] A felony of "knowing endangerment" exists if a person violates a RCRA requirement with the knowledge that another person may thereby be placed in imminent danger of death or serious bodily injury, and if the violator manifests an unjustified and inexcusable disregard or an extreme indifference for human life. The RCRA violations covered by the knowing endangerment provision are transporting waste to an unpermitted facility or treating, storing, or disposing of waste without a permit or in violation of a permit or omitting material from a permit application; or failing to abide by interim status regulations and standards for TSDFs.

Imminent Hazard

Under section 7003 of RCRA, EPA may sue in Federal court for injunctive relief upon receipt of evidence that the handling, storage, treatment, transportation, or disposal of any solid or hazardous waste may present an "imminent and substantial endangerment to health or the environment."[50] EPA interprets "imminent and substantial endangerment" as posing a "risk of harm" or "potential harm" but not requiring proof of actual harm. EPA is expressly authorized under the 1980 amendments to take any necessary action under the imminent hazard section, including the issuance of administrative orders, to protect public health and the environment.

Citizen Suits.—Section 7002 of RCRA provides that any person may initiate a citizen suit against any other person alleged to be in violation of a permit, regulation, or provision of RCRA whether or not Federal authorities have taken action.[51] Before filing suit, the plaintiff must give 60 days' notice to EPA, the States involved, and the alleged violator. A citizen suit may also be brought against EPA for failure to perform a nondiscretionary duty under RCRA. No advance notice need be given to EPA if the hazardous waste provisions of RCRA are involved. Citizen suits are an additional and potentially powerful mechanism for assuring that the intent of RCRA is carried out by those engaged in hazardous waste activities and by State and Federal agencies. Section 7002 authorizes the award of attorneys fees and litigation costs to any party whenever the court determines that such award is appropriate. (The party need not be the prevailing party in the case to recover the costs of bringing the lawsuit.)

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[47] RCRA sec. 3008, 42 U.S.C. 6928.
[48] 42 U.S.C. 6928 (d).
[49] Public Law 96-482, sec. 13, 94 Stat. 2339; 42 U.S.C. 6928 (e).
[50] 42 U.S.C. 6973.
[51] 42 U.S.C. 6972.

State Programs

Under RCRA section 3006, States may exercise primary responsibility for administration and enforcement of a hazardous waste management regulatory program under State law in lieu of the Federal EPA program provided that the State program meets certain minimum Federal standards.[82] RCRA also provides for interim authorization of existing State programs that allow the State to continue to administer its regulatory program instead of the Federal program while the final Federal program is being developed and the State permanent program applications are prepared and reviewed. In States with interim authorization or final authorization, generators, transporters, and facility operators are subject to a single hazardous waste regulatory program—without such authorization they would have to comply with both the Federal and State program requirements.

Congress anticipated that all States eventually would assume primacy for regulating hazardous waste management. RCRA offers two incentives for State participation: first, the opportunity for the State to administer its own program instead of having the Federal Government regulate hazardous waste in the State; and second, Federal grants and technical assistance for development and operation of State programs. Current economic conditions and budgetary constraints have made the continued availability of adequate Federal grants and technical assistance uncertain. Some State officials have suggested that uncertainty about the availability of these grants may induce some States to decline to regulate hazardous wastes and to allow the Federal Government to finance and operate the regulatory program within these States. Those instances, however, are expected to be few if Federal grants are maintained.

State Program Approval

Section 3006 of RCRA establishes the requirements and procedures for approval of State programs by comparing them to the Federal program. Implementation of the Federal RCRA program was then a precondition for State hazardous waste program development. Delays in promulgation of the Federal regulations delayed State program efforts. To help States develop acceptable regulatory programs, RCRA directed EPA to issue guidelines for State programs within 18 months (i.e., by April 1978). EPA missed this deadline. The guidelines were eventually issued in January 1980, and implementing regulations were finally issued in May 1980.

Section 3006 provides for two types of program authorization: interim authorization and final authorization.

Interim authorization is available to State programs in existence before 90 days after promulgation of the standards for the Federal permanent program (EPA has set this date as October 26, 1982) if the State program is **substantially equivalent** to the Federal program requirements. Final authorization is given to State programs that are fully equivalent **to the complete Federal regulatory program.**

EPA has divided the State interim authorization process into two phases which correspond roughly with the phases in development of TSDF standards.

Phase I Interim Authorization.—States may apply for phase I approval to operate State program requirements for identification and listing of hazardous waste, reporting, a manifest system, and preliminary standards for generators, transporters, and interim status TSDFs.

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[82] 42 U.S.C. 6926.

Phase II Interim Authorization.—States can receive interim authorization to permit TSDFs under State programs before final authorization. Phase II authorization includes permitting requirements, standards of general applicability, and technical standards for different types of TSDFs. Phase II approval is divided according to "components" corresponding to the facility standards issued by EPA:

- **Component A.**—Permitting of storage facilities: containers and tanks, based on Federal permit standards published on January 12, 1981,[53]
- **Component B.**—Permitting of incinerators and other treatment facilities based on EPA regulations issued January 23, 1981,[54] and
- **Component C.**—Permitting of land disposal facilities: landfills, surface impoundments, waste piles, and land treatment facilities based on EPA standards issued July 26, 1982.[55]

States cannot be authorized to issue RCRA permits for those TSDFs for which EPA has not issued technical permitting standards, for example, underground storage tanks, or chemical and biological treatment facilities. These facilities remain subject to Federal permitting and to any independent State requirements. States applying for interim authorization must obtain phase I authorization as a prerequisite to receiving phase II authorization, however, they may be granted simultaneously.

Demonstration of Substantial Equivalence

To obtain interim authorization, a State must show that it has an existing State program as defined by EPA rules, the State program is **substantially** equivalent to the Federal program requirements, and the State has an acceptable authorization plan outlining what changes will be made in the State program to qualify for final authorization.

Three tests are applied to demonstrate the substantial equivalence of a State program to the Federal interim status program.

1. **The State program must control substantially the same universe of waste as the Federal program so that there are no major gaps in coverage.** The State program must have provisions for identifying the characteristics of hazardous waste and for listing hazardous wastes so that the State program controls substantially the same universe of waste as the Federal program. In practice, this has meant that the States's listing requirements and hazardous waste characteristics must be nearly identical to the Federal regulations. If they are not the same, the State program must effectively control the same universe of waste plus contain a commitment to expand the State program to cover currently unregulated hazardous wastes within a reasonable period of time after interim authorization. (States may regulate a larger universe of hazardous waste than the EPA program; however, all wastes regulated under the Federal program must be in the State's universe of waste.

2. **The State program must have adequate regulatory authority to control generators, transporters, and operators of hazardous waste TSDFs including provisions for requiring compliance with permitting standards, reporting requirements, and with a manifest system.** The State program standards for permitting TSDFs must provide substantially the same level of protection for human health and the environment as the Federal facility standards.

3. **The State must show that it has adequate funding and personnel for administration and enforcement of the State program.**

During the interim authorization period, State programs can vary from the Federal program in listing and characterization methods. States that do not control certain hazardous wastes because those wastes are not generated or disposed of in the State may receive authorization provided that they commit to develop regulatory requirements to cover those wastes in the future.

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[53] 46 F.R. 2804. Note, the storage facility standards including standards, for surface storage impoundments and waste piles, were modified and became part of component C land disposal facilities published on July 26, 1982.

[54] 46 F.R. 7666. Note, these were modified for incinerators on June 24, 1982, 47 F.R. 27,520.

[55] 47 F.R. 32,274.

A State may operate its program under interim authorization until it receives final authorization. Under RCRA, the State must receive final authorization by January 26, 1985, or the Federal Government will resume regulatory authority over hazardous waste activities in the State. If a State does not apply for or receive interim or final authorization, hazardous waste activities in the State are subject to both the Federal program requirements and to other State regulations, if any.

States may apply for interim authorization at any time until close of the interim authorization period. With publication of the land disposal rules in July 1982, EPA announced that establishment of the permanent Federal program was largely complete and that it would begin to accept applications for final State authorization. Interim authorization lasts until 24 months after the effective date of the Federal permanent program regulations. EPA has announced that the interim authorization period will expire January 26, 1985. In applying for interim authorization, States commit to plan for upgrading their programs to qualify for final authorization by the end of the interim authorization period. Obtaining interim authorization is not a precondition for receiving final authorization. In fact, some States with existing programs may skip the interim authorization route and apply directly for final authorization. As of November 1, 1982, 35 States had qualified for phase I interim authorization and 5 States had received phase II interim authorization for components A and B. (See table 73 in in part II of this chapter.)

Partial Authorization and Cooperative Arrangements

Because some States may not have all the necessary authority or regulations to operate an acceptable State regulatory program during interim authorization, EPA has initiated partial program authorization and cooperative agreements.

Under partial authorization, EPA will approve those portions of a State program that meet the minimum Federal requirements for substantial equivalency with the Federal program while EPA administers and enforces the remaining elements of the Federal program. For example, if the State lacks adequate authority under State law to require compliance with a manifest system, EPA will nevertheless approve the rest of the State program for controlling hazardous waste activities provided that the State plan specifies the steps to be taken to get final authorization by the end of the interim authorization period. EPA will then administer and enforce the Federal manifest requirements for that State, while State requirements control other activities.

For States that cannot qualify for partial interim authorization, EPA has initiated a cooperative arrangement that allows the States to administer some functions of a hazardous waste management system for EPA, while EPA administers and enforces the remaining functions under the Federal program. These cooperative arrangements are different from partial authorization. The purposes of cooperative arrangements is to encourage States to adopt a State hazardous waste program by allowing them to administer portions of a State program in coordination with EPA while giving the States the time and opportunity to develop a satisfactory State program that can qualify for interim and/or final authorization.

Final Authorization of State Programs

Once final authorization is granted, the State hazardous waste regulatory program operates in lieu of the Federal program. The State assumes full authority to administer and enforce the RCRA hazardous waste regulatory system. On authorization, EPA's regulatory and permitting responsibilities will largely cease. Thereafter, if EPA exercises its enforcement power, it will enforce compliance with State program and permit requirements, not the Federal standards. EPA will retain its oversight and enforcement authority over the State program to ensure that it continues to operate effectively according to its approved plan. The Federal program requirements are not applicable in the State unless EPA revokes the State's final authorization. EPA will initially retain some regulatory responsibility for those waste management technologies for which Federal permitting standards have not been issued and which cannot therefore be permitted under an approved State program. States can, however, regulate and permit these facilities under State law. As EPA further refines and adds to the Federal program, States will be expected to make similar modifications and additions to their State program and to maintain equivalency and consistency.

Requirements for Final Authorization

To receive final authorization, a State must demonstrate that its program meets the requirements of section 3006(b):

- the State program is **equivalent** to the Federal program;
- the State program is **consistent** with the Federal program and with other State programs;
- the State has **adequate administrative resources** to operate a comprehensive program regulating hazardous waste generators, transporters, facility owners, and operators; and
- the State has **adequate enforcement authority** to require compliance with its program.

These requirements are more comprehensive than the substantial equivalency tests for interim authorization. The State must regulate the full universe of waste controlled under the Federal program with no gaps in coverage. The State must regulate generators, transporters, and TSDFs. The State facility standards must provide at least the same degree of protection of human health and the environment as the Federal standards. The State program must also have adequate opportunities for public participation in program development and in permitting procedures.

EPA has announced that it will now accept applications for final authorization of State programs.[56] Because RCRA requires a minimum period for review by EPA and public comment and hearing, EPA estimates that final program authorization will take a minimum of 6 months after submittal of a complete application. States must obtain final authorization by the end of the interim authorization period. **If the State program is not given final authorization by the end of the 24-month period (by Jan. 26, 1985), or if EPA makes a final determination rejecting the State's final program application, EPA must operate the Federal program in that State. EPA and the State must complete program development, review, public participation, and program approval within the next 2 years to meet EPA's announced goal of final authorization of 45 States by January 1985.**

One of the significant issues to be faced in final authorization will be how to treat State programs that are significantly different from the Federal program. Guidance will have to be developed to demonstrate equivalency, consistency, and adequacy. Under RCRA section 3009, once EPA has issued regulations dealing with any aspect of hazardous waste activity, any State regulations on the same subject may not be less stringent than the Federal requirements.[57] The 1980 Solid Waste Disposal Act amendments reinforced, however, that a State may have **more stringent** provisions than the Federal program. However, **just how much more stringent State program requirements may be without being considered inconsistent with the Federal or other State programs, or being held unconstitutional as a restraint on interstate commerce, is an open question. This question will become more controversial as some States adopt considerably more stringent restrictions on hazardous waste activities, such as banning land disposal of certain recyclable or extremely dangerous wastes or imposing more difficult technical requirements on existing and new facilities.**

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[56] 47 F.R. 32,382, July 26, 1982.

[57] 42 U.S.C. 6929.

Superfund

Introduction

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), or "Superfund," was a compromise measure.[58] Legislation to provide for emergency response and cleanup for chemical spills and releases from hazardous waste sites and to provide compensation for damages from these incidents had been considered in previous Congresses. But such legislation had met substantial opposition because of several controversial provisions dealing with liability for damages and creation of a cleanup trust fund financed by taxing the oil and chemical industries.

CERCLA authorizes the Federal Government to respond directly in the event of chemical spills and releases of **hazardous substances** into the environment. The framework for coordinated Government response is established by the National Contingency Plan (NCP). To pay for emergency response and cleanup actions, CERCLA created the Hazardous Substance Response Trust Fund financed by a tax on crude oil, imported petroleum, and certain chemicals. The collection of the Superfund tax is authorized for 5 years (until the end of fiscal year 1985) or until the total unobligated balance in the Response Trust Fund established under CERCLA reaches $900 million or a total of $1.38 billion has been collected, whichever occurs first. The total amount expected to be available in the Superfund trust fund is $1.6 billion.[59]

CERCLA also created a second fund, the Post-Closure Liability Trust Fund, to pay for post-closure care, remedial action, and damages from releases at qualifying hazardous waste facilities. The $200 million post-closure trust fund is financed by a tax on hazardous waste received at treatment or disposal facilities and which will remain in the facility after closure.

One of the most important provisions of CERCLA allows the Government to recover the costs of such response and remedial action. CERCLA imposes **strict liability** for the cost of Government response actions and damages to natural resources on those **responsible parties** whose actions cause release of hazardous substances. The liability for cleanup costs under CERCLA is far-reaching. It places the ultimate responsibility for cleanup costs on the past and present owners or operators of facilities, on the transporters who accepted waste for transport and selected the facility, and on the generators whose wastes were sent to the facility.

Hazardous Substances Under CERCLA

The Government may take response action under CERCLA whenever there is a release or threat of release of a **hazardous substance or of any pollutant or contaminant** which may present an **imminent and substantial danger** to public health, welfare, or the environment.

The range of substances for which response action is authorized in CERCLA is significantly broader than the universe of hazardous waste under RCRA. A **hazardous substance** as defined in section 101(14)[60] of CERCLA includes:

> (A) any hazardous substance designated pursuant to section 311(b)(2)(A) of the the Clean Water Act;
> (B) any element, compound, mixture, solution, or substance designated pursuant to section 102 of CERCLA;
> (C) any RCRA hazardous waste;
> (D) any toxic pollutant listed under section 307(a) of the Clean Water Act;
> (E) any hazardous air pollutant designated under section 112 of the Clean Air Act; and
> (F) any imminently hazardous chemical substance or mixture under section 7 of the Toxic Substances Control Act.

Response actions are not limited to releases of the hazardous substances defined above; releases of "pollutants or contaminants" are also covered. For example, a material excluded from regulation under RCRA or other laws could nevertheless be considered as a "pollutant or contaminant" under CERCLA. Under section 104(b) of CERCLA "pollutant or contaminant" includes but is not limited to:

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[58] Public Law 96-510, 94 Stat. 2767, Dec. 11, 1980; 42 U.S.C. 9601 et seq.

[59] Of the total $1.6 billion, $1.38 billion will come from the Superfund tax and $0.22 billion from appropriated funds.

[60] 94 Stat. 2769; 42 U.S.C. 9601 (14).

> . . . any element, substance, compound, or mixture, including disease-causing agents, which after release into the environment and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction) or physical deformations, in such organisms or their offspring.[61]

The definitions of "hazardous substance" and "pollution or contaminant" specifically exclude petroleum, natural gas, natural gas liquids, liquified natural gas, and synthetic gas unless designated as a hazardous substance under CERCLA or other laws.

Reportable Quantities.—Section 102[62] of CERCLA provides for the establishment of reportable quantities of hazardous substances. Any release of these substances exceeding specified amounts must be promptly reported to the National Response Center (NRC). The initial reportable quantity is 1 lb except for those hazardous substances for which different reportable quantities have been set under section 311(b)(4) of CWA.[63] EPA is authorized to adjust the initial reportable quantities, as appropriate. EPA may designate additional "hazardous substances" subject to the reporting requirements if release of such substances may present a substantial danger to the public health, welfare, or the environment. Failure to report a release of a reportable quantity is punishable by fine or imprisonment. To encourage reporting, section 102(b) provides that neither the notification nor any information derived from it may be used against the person reporting in any criminal action except in prosecutions for perjury or false statement.

Notification of Inactive Waste Management Sites

Section 103 of CERCLA requires that the location of any facility where hazardous substances have been treated, stored, or disposed of and which is not permitted or accorded interim status under RCRA must be reported to EPA by June 10, 1981.[64] This notification requirement applies to the past or present owners or operators of the facilities and to any persons who accepted hazardous substances for transportation and selected a facility for storage treatment or disposal. The notification must identify the location of the facility, the amount and type of hazardous substance found there, and any known, suspected, or likely release of such substances from the facility. EPA is to notify a State of the existence of any such facility in that State. Section 102 directs EPA to issue regulations specifying the types of records to be maintained by the persons giving notice. These records must be maintained for 50 years from enactment of CERCLA or from the date the record was established, whichever is later.

Section 103 imposes stiff penalties for failure to comply with notification or recordkeeping requirements. In addition, persons who fail to report as required may not invoke the defenses against liability and the limitations on liability for cost recovery and environmental damages available to responsible parties.

The reportable quantities, notification, and recordkeeping requirements are not applicable to:

- permitted or interim status facilities under RCRA;
- federally permitted releases (as defined in sec. 101(10) of CERCLA);[65]
- application or storage of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) registered pesticides by an agricultural producer;

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[61] 94 Stat. 2775; 42 U.S.C. 9604 (a)(2).

[62] 94 Stat. 2772; 42 U.S.C. 9602.

[63] A list of these reportable quantities is found at 40 C.F.R. 117.3 (1982).

[64] 94 Stat. 2773; 42 U.S.C. 9603 (c).

[65] 94 Stat. 2768; 42 U.S.C. 9601 (10).

- releases of a consumer product;
- releases of hazardous substances that are required to be reported or that are exempted from reporting under RCRA; or
- continuous releases that are stable in quantity and regularity, and which have already been reported to the NRC. (Continuous releases must be reported annually, and the NRC must be notified immediately of any statistically significant increases in quantity.)

Response Authority Under CERCLA

Section 104 of CERCLA establishes an extremely broad Federal response mechanism to deal with releases or threatened releases of hazardous substances into the environment.[66] The section authorizes the President to take whatever action is deemed necessary to remove, arrange for removal, provide remedial action, or any other action consistent with the NCP necessary to protect public health or welfare or the environment. By Executive Order, the President has delegated primary responsibility for carrying out the response activities under CERCLA to EPA.[67]

Direct Government action is authorized in cases of a release or a threatened release unless it is determined that response action will "be done properly by the owner or operator of the facility or vessel from which the release or threat of release emanates, or by any other responsible party."[68] The term "facility" is also given an expansive definition in CERCLA:

> . . . "facility" means (A) any building, structure, installation, equipment, pipe or pipeline (including any pipe into a sewer or publicly owned treatment works), well, pit, pond, lagoon, impoundment, ditch, landfill, storage container, motor vehicle, rolling stock, or aircraft, or (B) any site or area where a hazardous substance has been deposited, stored, disposed of, or placed, or otherwise came to be located; but does not include any consumer product in consumer use or any vessel.[69]

CERCLA authorizes the President to take direct Government action to remove or mitigate the threat in the event of a release or threatened release of a hazardous substance, pollutant, or contaminant which presents an imminent and substantial threat to human health and welfare or to the environment. Two types of response actions can be financed by the Response Trust Fund: removal actions and remedial actions.

A **removal action** is a short-term emergency response action designed to remove or mitigate an immediate threat to health, welfare, or the environment. Fund expenditures for removal actions are limited to $1 million or 6 months duration from the date of the initial response. These limits may be exceeded if there is a continued and substantial immediate threat to human health and the environment and the required action is unlikely to be performed by any other party.

In contrast, **remedial action** is a long-term action directed at a permanent remedy to remove or correct the threat caused by the release of hazardous substances to the environment. Remedial actions are limited to sites that are listed on the National Priority List and where no responsible party will take prompt effective action to correct the situation. **Before a fund-financed remedial action can be taken, the State must enter into a cooperative agreement or contract with EPA to assure all future maintenance of the remedial response at the site for the life of the response action, to assure the availability of adequate offsite treatment, storage, or disposal capacity, and to contribute 10 percent of total remedial action costs. (If, however, the site was owned by a State or locality at the time the hazardous substance was deposited, the required contribution is 50 percent or more of the costs depending on the degree of culpability.)** CERCLA requires that any remedial actions must be consistent to the extent practicable with the NCP.

Government action under section 104 of CERCLA is not limited to instances when the occurrence or threat of a release is known. **The act authorizes investigative actions, monitor-**

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[66] 94 Stat. 2774; 42 U.S.C. 9604.

[67] Executive Order 12316, 46 F.R. 42,237, May 12, 1981.

[68] 94 Stat. 2774; 42 U.S.C. 9604 (a)(1).

[69] 94 Stat. 2769; 42 U.S.C. 9601 (9). Vessels are separately defined as any watercraft.

ing, testing, and surveys to determine whether a suspected release has occurred or might occur. A release might be suspected on the basis of an outbreak of illness or disease, or complaints of illness or disease that might be attributable to exposure to a hazardous substance, pollutant, or contaminant. Section 104 also authorizes expenditures for any additional planning, legal, fiscal, economic, engineering, architectural, or other studies or investigations necessary or appropriate to plan or direct response actions, or to pursue cost recovery and enforcement actions under section 107.

Abatement Orders

In addition to direct Government response, CERCLA also provides for administrative and judicial **abatement actions** to compel cleanup by responsible parties. Section 106 authorizes EPA to issue administrative orders to owners or operators of facilities or to other persons to take necessary action to abate an **imminent and substantial threat** caused by a release or threatened release.[70] These administrative orders are enforceable in Federal court. Alternatively, the Administrator may ask the Department of Justice to seek appropriate relief from a Federal court, such as an injunction against a responsible party requiring cleanup or performance of necessary investigations, or supplying alternate drinking water supplies to the affected communities. Fines of $5,000 per day can be assessed for violations of abatement orders. Additionally, the Government may seek punitive damages of three times the cleanup costs under a section 107 cost recovery action if a responsible party does not comply with an abatement order.

Cost Recovery Actions

Under section 107 of CERCLA, the Government may sue to recover the costs of remedial action, damages for harm to natural resources, and administrative costs.[71] In appropriate cases, the Government may sue for punitive damages from owners and operators of facilities, transporters, generators, site owners, and other responsible parties.

It is generally agreed that CERCLA imposes **strict liability** in cost recovery actions. CERCLA specifies that it imposes the same standard of liability as section 311 of CWA. Courts have held that section 311 imposes strict liability and joint and several liability. A major issue in cost-recovery actions is the extent to which CERCLA may impose joint and several liability for remedial action costs. CERCLA is silent on the issue. Language that would have expressly applied the doctrine of joint and several liability to Superfund actions was dropped as part of the compromise to pass the legislation. Congress left the issue to be resolved by the courts applying common law theories. EPA and the Department of Justice have taken the position that joint and several liability is available under statutory and common law principles in Superfund actions.

A second issue is the degree of contribution available from others to responsible parties who have been held liable. This issue has not yet been litigated to conclusion and is expected to become increasingly prominent as Federal and State enforcement actions proceed.

Initial settlements negotiated between the Federal Government for several interim National Priority List sites have involved many responsible parties. The potential availability of joint and several liability may have prompted many of these parties to settle. Section 107 can also be used prospectively to seek advance payment for cleanup from parties who contributed to the problem at a particular site. Before filing suit, notices of the planned section 106 and 107 actions are usually sent by Federal enforcement officials to potentially responsible parties in an attempt to encourage the parties to enter settlement negotiations with EPA to achieve site cleanup. This advance notice and the opportunity for negotiations are not required. As an incentive to negotiate, EPA might agree not to proceed further against the settling parties for additional site cleanup costs in appropriate cases.

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[70] 94 Stat. 2780; 42 U.S.C. 9606.

[71] 94 Stat. 2781; 42 U.S.C. 9607.

The National Contingency Plan

The principal mechanism for implementing the Government response under CERCLA and for determining the extent of liability under the cost-recovery provisions of section 107 is the NCP. Section 105 of CERCLA directs EPA to revise and republish NCP—which was originally established under section 311 of CWA to deal with oil and chemical spill emergency response and cleanup—to include a new national hazardous substance response plan specifying the procedures and standards for Government response to hazardous substances releases.[72] The revised NCP was to be published within 180 days of enactment of CERCLA after opportunity for public review and comment (i.e., June 1981). This deadline was missed, and the NCP was eventually published under court order on July 16, 1982.[73]

NCP is intended to provide a comprehensive framework for the national response program for hazardous substance spills and releases. Section 105 requires that NCP specify the procedures, techniques, materials, equipment, and methods to be used in identifying, removing, or remedying releases of hazardous substances. It must also include methods for ranking sites, analyzing costs, and determining the appropriate remedy. The plan should specify appropriate roles for Federal and State agencies and nongovernmental groups in responding to releases. After the revised NCP becomes effective, all response actions must be in accordance with NCP to the maximum extent practicable.

By far the most important aspects of NCP are the methods for evaluation of releases, for determining the appropriate extent of remedy, and for assuring cost effectiveness of the response action and the criteria for establishing the National Priority List (NPL). The July 1982 NCP sets forth EPA's basic approach to these congressional directives. Overall, EPA has preferred a flexible, site-specific approach.

The National Priority List

Criteria for Ranking Sites for NPL.—Congress directed EPA to develop and apply criteria for establishing priorities among sites for response actions based on their relative degree of risk or danger to public health, welfare, or the environment. In ranking the sites by the degree of risk posed, EPA was to consider to the extent practicable:

- the population at risk;
- the hazard potential of the hazardous substances at the facility;
- the potential for contamination of drinking water supplies;
- the potential for direct human contact;
- the potential for destruction of sensitive ecosystems;
- State preparedness to assure State costs and responsibility; and
- other appropriate factors.

Based on these criteria and on consultation with and recommendations from the States, EPA was to publish, as part of NCP, the NPL, which will rank actual or threatened releases across the country. Sites must be on the NPL to qualify for Superfund-financed remedial actions. Section 105 requires that the list contain to the extent practicable at least 400 of the highest priority facilities, to be referred to as "top priority among known response targets." Section 105 further provides that to the extent practicable, the top 100 of these priority targets should include one site designated by each State as the facility posing the greatest danger to public health, welfare, or the environment among known facilities in that State. The States are to use the ranking criteria in establishing priorities among their sites. EPA is to revise the NPL at least annually in consultation with the States.

The NCP published in July 1982 did not contain the final NPL because more time was needed to gather adequate information to complete the list, and to allow the States to apply the ranking criteria to their recommended sites as required under CERCLA and the NCP. An initial proposed NPL of 115 sites was published for comment in October 1981, and 45 additional sites were added to that list in July 1982. EPA published in December 1982 its proposed NPL of 418 sites as appendix B to the NCP.[74]

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[72] 94 Stat. 2779; 42 U.S.C. 9605.

[73] 47 F.R. 31,180, to be codified at 40 CFR part 300.

The Hazard Ranking System.—In response to the directive to establish criteria for setting priorities among releases of hazardous substances for the purposes of taking removal and remedial action, EPA adopted the Hazard Ranking System (HRS), published as appendix A of NCP. (The HRS is also known as the "Mitre Model.") EPA and the States apply the HRS using data from observed or potential releases to obtain a score representing an estimate of the risk presented by each release. The score for each release is then used with other considerations in determining whether a site is placed on the NPL.

The States apply the HRS in submitting their recommended sites and in designating the sites posing the greatest hazard. The EPA regional offices will review the States' ranking before forwarding their recommendations for inclusion on the NPL. Among the most significant practical problems encountered by the States is that the HRS requires more detailed information on the sites than is generally easily available. Although the system does allow the use of standardized factors in the absence of detailed site information, if too many data requirements are missing, the site cannot be ranked. **No Federal funds are currently available for States to obtain this information.** OTA and others have raised questions about the adequacy or appropriateness of the methodology used in the HRS to distinguish between the relative degrees of risk posed at different sites. (See part III and the appendix to this chapter for a discussion of some of the scientific and technical difficulties in the design and use of the HRS.)

State Participation

Under section 104(d) of CERCLA, the Federal Government can enter into contracts or cooperative agreements with States or local governments to carry out any authorized response actions in accordance with the NCP. Under such an agreement, the States or local governments will be reimbursed by Superfund for their reasonable response costs consistent with the NCP. These contracts will be subject to the above cost-sharing requirements. Section 105 requires that the NCP specify appropriate roles for Federal, State, and local government agencies. The NCP calls for State and local government participation on regional response teams. Additionally, under a contract or cooperative agreement, a State agency may be designated as the lead agency and as the on-scene coordinator in response activities. Preliminary EPA experience with site evaluations for response actions has been that State agencies have assumed "lead" responsibilities in over 70 percent of these cases.[75] EPA may advance 90 percent of the estimated evaluation costs to the state agency under a contract or cooperative agreement.

Responses to Hazardous Substance Releases Under the National Contingency Plan

The NCP establishes the overall approach that EPA will use in dealing with releases or threatened releases of hazardous substances or of pollutants or contaminants that pose a substantial and imminent danger. EPA has segmented its site evaluation and response procedures under the NCP so that fund-financed activities are carried out in a series of limited, highly structured, sequential phases. At the same time, EPA will, in appropriate cases, pursue settlement negotiations or enforcement actions against known potentially liable parties to secure private cleanup or to recover costs. Under subsection F of the NCP, EPA has set up a response procedure with seven phases as shown in table 57. At various phases in the response procedure, sites can be excluded from further response activities.

Phase I—Site Discovery and Notification.—A release or threatened release is reported to

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[74] 47 F.R. 58,475, Dec. 30, 1982.

[75] Remarks of William N. Hedeman, Director, EPA Office of Emergency and Remedial Response Before the ALI-ABA conference on Hazardous Wastes, Superfund, and Toxic Substances, Washington, D.C., Nov. 4, 1982.

Table 57.—National Contingency Plan—Phases of Response Actions

Criteria	Action
Phase I: Site Discovery and Notification	
Possible release or threatened release of hazardous substances indicated by notice of inactive site, of release in reportable quanitities, or of other complaint.	Release reported to National Response Center and to affected State.
Phase II: Preliminary Assessment	
Site recommended for further evaluation or immediate removal. No further action at site recommended: 1) there is no release; 2) a hazardous substance, pollutant, or contaminant is not involved; 3) the source is not subject to CERCLA; 4) release amount does not warrant Federal response; or 5) a responsible party is taking appropriate action and government monitoring is not needed.	Determine nature, extent, and source of release and the magnitude of hazard based on available data. Make recommendation for further action.
Phase III: Immediate Removal Action	
Rapid emergency response required if site poses threat of immediate and significant harm from: 1) human, animal, or food chain exposure to acutely toxic substances; 2) contamination of drinking water supplies; 3) fire or explosion; or 4) other acute situation.	Take appropriate immediate removal action, such as: 1) measuring and sampling; 2) removing hazardous substances from site; 3) restraining spread of release by physical, chemical, or other means; 4) preventing access to site by fencing or other means; 5) providing substitute drinking water; 6) controlling source of release; 7) recommending evaluation of threatened population; or 8) any other appropriate emergency measures.
Phase IV: Site Evaluation and Determination of Appropriate Level of Response	
Appropriate level of response: • Immediate removal—emergency threat to health or the environment (see Phase III). • Planned removal—short-term, but not emergency response (see Phase V). • Site recommended for National Priority List remedial action (see Phase VI). • No further action/evaluation recommended.	Conduct site evaluation, data collection, and site investigations; determine type, amounts, and locations of hazardous substances and potential for migration; determine appropriate level of response; recommend site for immediate removal, planned removal, National Priority List remedial action candidate (apply HRS), or no further action.
Phase V: Planned Removal	
Planned removal is authorized where: • Substantial cost-saving can be achieved by continuing an immediate removal action; or • A serious risk to public health or the environment exists from exposure to hazardous substances which requires short-term, but not emergency response at a facility not ranked on the National Priority List. A serious risk may involve: 1) actual or potential direct contract with hazardous substances by nearby populations; 2) contaminated drinking water at the tap; 3) hazardous substances in drums, tanks, or other bulk storage containers; 4) highly contaminated soils at or near the surface; 5) threat of fire or explosion; or 6) weather conditions that may cause substances to mitigate.	• Determine whether site qualifies for planned removal. • Take appropriate response action to reduce or remove serious risk to public or the environment: State requests removal and agrees to assure future operations and maintenance at site, and availability of offsite treatment, storage, disposal capacity and to provide State cost-share. • Planned removal action completed when serious risk is abated or 6 months/$1 million limit is reached.
Phase VI: Remedial Actions	
Responses to sites ranked on the National Priority List that are consistent with a permanent remedy to prevent or mitigate migration of release of hazardous substances into the environment. *The appropriate extent of remedy is: 1) the lowest cost remedial alternative that is technologically feasible and reliable and which effectively minimizes or mitigates danger to or provides adequate protection of public health, welfare and environment.* Remedial actions include: 1. *Intitial remedial measures*—those measures which should begin quickly if they are feasible and necessary to limit exposure or threat of exposure to a significant health or environmental hazard and if they are cost effective. Situations where initial remedial measures are appropriate are similar to planned removals at unranked sites.	Evaluate National Priority List sites and determine appropriate remedy (see also fig. 22): • Conduct *preliminary assessment* of type(s) of remedial action which may be appropriate: —initial remedial action, —source control remedial action, and —offsite remedial action. • Take initial remedial action if indicated. • Perform remedial investigation to determine nature and extent of problems posed by release and necessity for and extent of proposed remedial action. • Assess remedial alternatives: —"initial screening"—develop and analyze potential alternative remedial actions considering relative costs, effectiveness (including potential adverse effects), and feasibility according to acceptable engineering practices; and

Table 57.—National Contingency Plan—Phases of Response Actions—Continued

Criteria	Action
2. *Source control remedial actions*—may be appropriate if a substantial concentration of substances remain onsite and inadequate barriers exist to retard migration offsite; alternatives include containing wastes at the site or removing them. 3. *Offsite remedial action*—may be appropriate to minimize the migration of hazardous substances and the effects of such migration where source control actions may not be effective to remove or reduce a significant threat to human health or the environment. 4. *No action*—appropriate where response action may pose greater danger to the health or the environment than no action. Approval of fund-financed remedial action at a site must balance need for immediate action to protect health and welfare or the environment at that site against availability of money in the fund to respond to problems at other sites.	—"detailed analysis"—conduct detailed "feasibility" study of limited number of alternatives selected after initial screening with focus or relative costs. • Determine appropriate extent of remedy from alternatives. • Proceed with selected remedial action if State assurances and contribution requirements are met (and if timely and adequate response will not be taken by responsible parties or others) and if fund-financing request is approved.
Phase VII: Cost Recovery and Documentation Response Trust Fund will compensate authorized government or private response costs that are consistent with the NCP. (Cost recovery action may be pursued against responsible parties to reimburse Response Trust Fund).	Complete documentation of government response action, including nature of release, circumstances of response, costs to Federal Government, impacts on health, welfare or the environment, and identities of potentially responsible parties.

SOURCE: 47 F.R. 31,213, July 16, 1982, to be codified at 40 CFR 300, Subpart F.

NRC as a result of notification requirements under CERCLA or Federal permits, or through the inventory of inactive dump sites, citizen complaints, or other action. NRC will notify the appropriate State and Federal agencies to begin initial investigation.

Phase II—Preliminary Assessment.—The lead agency will make a preliminary investigation of the site to determine the magnitude of the hazard, the source and nature of the release, whether non-Federal parties will take prompt and appropriate response, and whether immediate removal is necessary. This assessment is based on readily available data, interviews, and site visits, if appropriate. The preliminary assessment phase ends with a recommendation for further evaluation of the site, a request for any necessary immediate removal action, or a recommendation that no further action be taken at the site.

Phase III—Immediate Removal.—Short-term emergency response action is taken to prevent or mitigate immediate and significant risk of harm to human life, health, or the environment. Circumstances under which immediate removal action may be indicated include threats of:

- human, animal, or food-chain exposure to acutely toxic substances;
- contamination of drinking water supplies;
- fire or explosion; or
- similarly acute situations.

Immediate removal actions are primarily defensive and include sampling, removing containerized wastes, fencing the site, or providing alternative drinking water supplies. Immediate removal operations are subject to an expenditure limit of $1 million or a duration of 6 months from the initial response unless continued response actions are urgently required because of an emergency situation involving an immediate risk to health or the environment **and** no other party will provide the necessary response on a timely basis.

Immediate removal operations are complete when the original acute situation is abated and any contaminated materials moved offsite have been treated or disposed of properly.

Phase IV—Evaluation and Determination of Appropriate Response.—If a preliminary assessment indicates that further response is necessary beyond any immediate removal actions, site evaluation is begun to determine the appropriate response required, if any. The lead agency will obtain the necessary information and conduct a site inspection to determine if there is any immediate danger to persons living or working nearby. These efforts are directed at identifying immediate threats to the public or the environment, the need for any immediate removal action; the amounts, types, and location of the hazardous substances at the facility; and the potential for the substances to migrate from their original location. As a result of site evaluation, States may suggest that the facility be added to the NPL. States must use the EPA ranking system in recommending priority sites. The results of the evaluation are used to decide whether the site is a candidate for immediate removal or planned removal, or should be added to the NPL as a candidate for fund-financed remedial action.

Phase V—Planned Removal.—For situations that pose a risk to public health, welfare, or the environment, and that require short-term, but not emergency response, planned removals may be undertaken. Planned removals are contemplated under the NCP for facilities that are not "ranked" (listed on the NPL) and where either a substantial cost-saving could be achieved by continuing a Phase III immediate removal action, or where the public or the environment will be at risk from exposure to hazardous substances. Planned removals are a "hybrid" response created by EPA for the NCP based on the two CERCLA response actions, removal and remedial action, and on EPA's general administrative authority over Federal grants. Planned removals are subject to the $1 million and/or 6 months expenditure limitation of removal actions and also to State contribution requirements nearly identical to those for remedial actions.

Table 57 summarizes the factors to be considered in determining whether a serious threat to public health and safety exists and whether planned removal actions are appropriate. Planned removal actions end when the conditions causing serious risk have been abated and any substances moved offsite have been properly treated or disposed of, or when 6 months have elapsed, or $1 million has been spent, whichever occurs first. Planned removal actions can exceed the 6 month/$1 million limit if an immediate threat remains or it is cost effective to continue cleanup.

Phase VI—Remedial Actions.—Remedial actions are responses to "ranked" sites on the NPL that are consistent with a permanent remedy to prevent or mitigate the migration of a release of hazardous substances into the environment. **A detailed evaluation of the proposed appropriate remedial action and the alternatives, including relative costs, must be conducted before a determination is made on the appropriate extent of remedy to be applied at the facility.** The NCP identifies three distinct types of remedial actions: initial remedial measures, source control actions, and offsite remedial actions. The appropriate extent of remedial action for a particular release may include one or more of these options or a "no action" response.

Initial remedial measures are actions that should begin quickly if they are feasible or necessary to limit exposure to a significant health or environmental hazard and which are cost effective. Unlike immediate removal actions, initial remedial actions are subject to State cost-share requirements. Initial remedial actions are begun before detailed analysis and final selection of an appropriate remedy.

Source control remedial actions might be appropriate if a substantial concentration of substances remains onsite and existing barriers are inadequate to retard migration offsite. Source control remedial actions may include alternatives to contain the hazardous substances where they are located or to eliminate potential contamination by moving the substances to a new location.

Offsite remedial action may be taken to minimize and mitigate the migration of hazardous substances and the effects of the migration that pose a significant threat to public health, welfare, or the environment. Offsite measures frequently involve ground water contamination problems. These actions can include providing permanent alternate drinking water supplies, controlling of a drinking water aquifer plume, or treatment of drinking water aquifers.

Assessment of Remedial Action.—The NCP requires EPA to assess the site before deciding which type or combination of remedial actions should be taken. This assessment process for NPL sites is shown in figure 22. Scoping is the first step in deciding the type and extent of remedial action to be taken in response to a release. The lead agency in cooperation with the State will examine the available information and decide, based on factors in the NCP, the type of remedial action needed. The scoping results will then be used as the basis for requesting funding for remedial investigation and feasibility studies. As the remedial investigation proceeds, the approach can be modified if indicated.

A remedial investigation is performed to determine the nature and extent of the problems posed by the release. This may include sampling, monitoring, and other information-gathering sufficient to determine the need for and the extent of proposed remedial action.

The lead agency then develops a limited number of alternatives for source control and/or offsite remedial actions depending on the type of response identified as appropriate. One alternative may be "no action" which could be appropriate if the response action could pose a greater environmental or health danger than no action. The alternative remedial actions are developed based on the assessments of the factors considered for each type of remedial action,[76] and the results of the remedial investigation.[77]

The alternatives are then subjected to an initial screening to narrow the list of potential remedial strategies for further detailed analysis. Three broad criteria are used in the initial screening:

- the cost of installing or implementing each alternative remedial action, including operation and maintenance;
- the effects of each alternative and feasibility according to each and feasibility according to each alternative; and
- acceptable engineering practices.

After the initial screening, more detailed analysis will be conducted of the remaining alternatives; this analysis will include:

1. refinement and specification of alternatives with emphasis on the use of established technology;
2. detailed cost estimation including distribution of costs over time;
3. evaluation in terms of engineering implementation or constructability;
4. an assessment of each alternative in terms of the extent to which it is expected to mitigate and minimize damages to, and provide adequate protection of, public health, welfare, and the environment relative to the other alternatives analyzed; and
5. an analysis of any adverse environmental impacts, methods for mitigating these impacts, and costs of mitigation.

Based on this comparative evaluation of the alternative remedial actions, the lead agency will then determine the appropriate extent of remedy. This alternative is to be the one that the agency determines is cost effective (i.e., "the lowest cost alternative that is technologically feasible and reliable and which effectively mitigates and minimizes damage to and provides adequate protection of public health, welfare, and the environment").[78] In selecting the appropriate extent of remedy, the lead agency must also consider the need to respond to other releases with fund money. Section 104(c) of CERCLA requires that the need for protection at the facility under consideration be balanced against the amount of money in the fund available to respond to other sites present or future problems, taking into consideration the need for immediate action.

The determination of appropriate remedy will decide what action, if any, will be taken to remove or reduce the danger to the public and the environment from a release, and how

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[76] 47 F.R. 31,216, to be codified at 40 CFR 300.68(e).

[77] 47 F.R. 31,216, to a codified at 40 CFR 300.68(f).

[78] 47 F.R. 31,217, to be codified at 40 CFR 300.68(j).

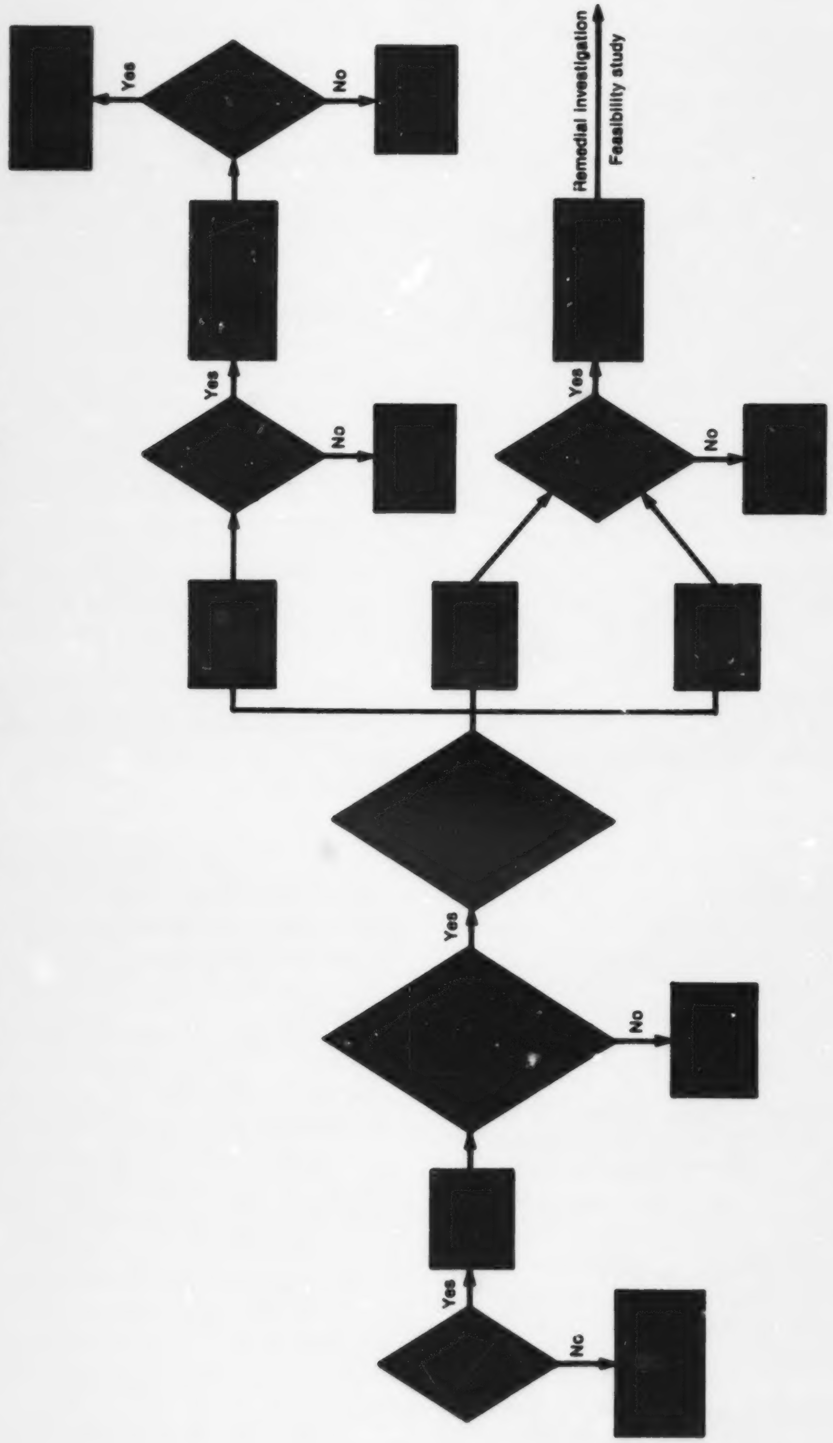
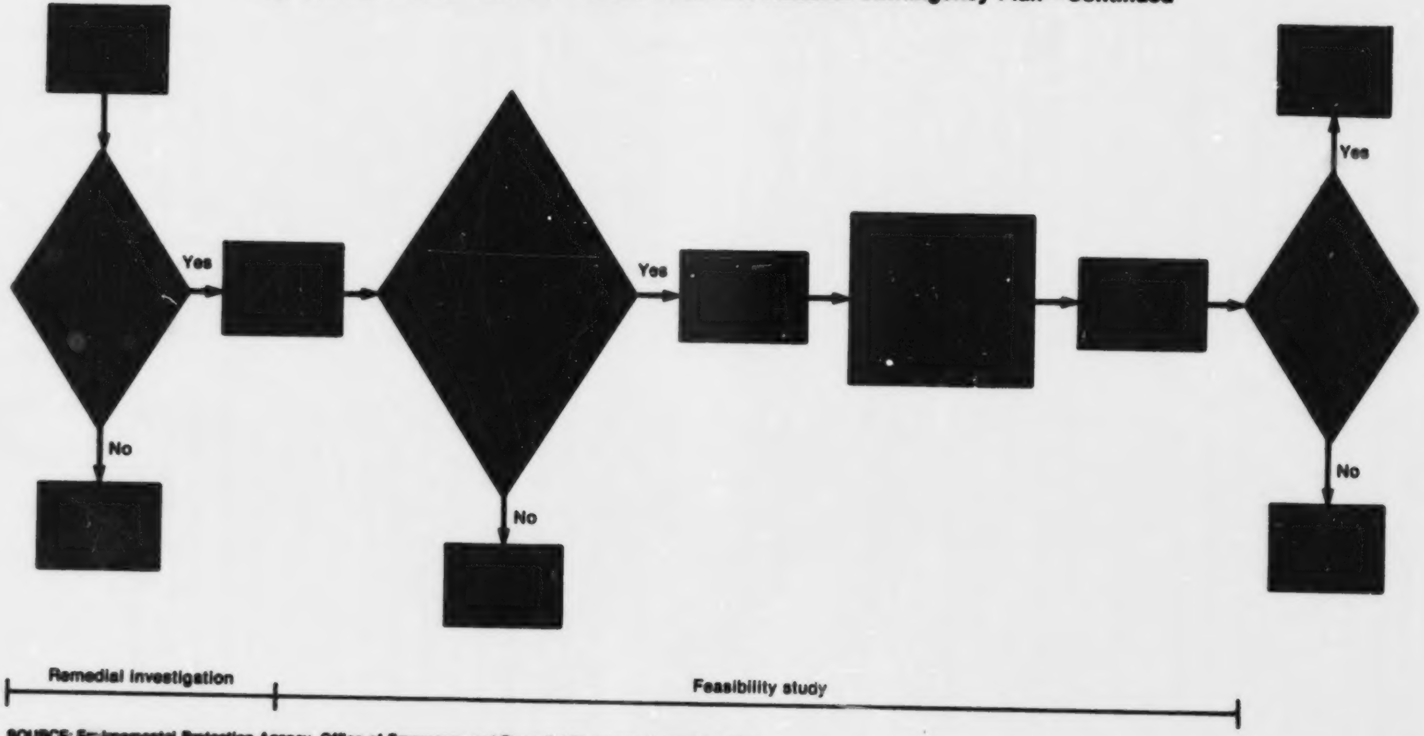

No
Yes
No
Yes
Yes
No
Yes
No
Yes
No
Yes
Remedial investigation
Feasibility study

Figure 22.—Remedial Action Process Under the National Contingency Plan

Figure 22.—Remedial Action Process Under the National Contingency Plan—Continued


Yes
No
Yes
No
Yes
No
Remedial investigation
Feasibility study

SOURCE: Environmental Protection Agency, Office of Emergency and Remedial Response, November 1982.

and to what extent the site will be cleaned up. Because appropriate remedial action measures under the NCP can consist of temporary or "band-aid" approaches to stabilize sites that pose a threat while leaving the hazardous substances at the location, some choices of remedy may be controversial. The discretionary aspect of the remedial action decision under CERCLA and the requirement to balance the need for cleanup or action at one site against present or future needs to act at other sites creates an internal tension in carrying out the cleanup mandate of CERCLA. **This dilemma between protecting the fund and removing risks to the public and the environment is frequently referred to as the "How clean is clean?" issue. Superfund cleanups under the NCP's flexible standard of protection may not result in removal of toxic substances from the site.** Contaminated soils and ground waters need not be restored to their original uncontaminated condition, but only to a level that does not pose a substantial threat. In some cases, the NCP provides that a "no action" alternative could be an appropriate remedy for an abandoned chemical dump site. **Each decision will be made on an ad hoc basis; each site will be treated as unique.**

Phase VII—Cost Recovery.—The final stage of response action under the NCP is documentation and cost recovery. All documentation on the extent of the release and remedial action, the circumstances leading to the release, and the identity of any potentially responsible parties plus an accurate accounting of all Federal costs incurred and impacts on public health, welfare, or the environment are forwarded to the regional response team, to the national response team, and to others as appropriate. Claims for response costs against Superfund must first be presented to the owner or operator of the facility or to other potentially liable parties. If these parties cannot be identified, or cannot, or will not, pay for the response, then a claim can be made against the Response Trust Fund.

Cleanup by Responsible Private Parties

In many instances, EPA anticipates that instead of, or in addition to, fund-financed remedial action, private parties who are responsible for the release will initiate action to clean up the site and to mitigate any threat to the public or the environment. The participation of responsible parties may be through voluntary agreement or as a result of administrative or judicial actions. Because sites considered for remedial action on the NPL have been found to be a significant threat to public health and the environment, the lead agency will usually review the cleanup proposals submitted by the responsible private parties. EPA may be asked to specify the level of cleanup to be required through enforcement action. In judging whether proposed private cleanup actions will effectively reduce or remove the threat, EPA will apply the same criteria used in assessing fund-financed remedial actions. The cost-balancing considerations required under section 104(c) of CERCLA are not applicable to determining the appropriate extent of responsible party cleanup.

Private cleanup may offer some significant cost advantages over fund-financed action. For example, in the Seymour Recycling settlement, a group of 24 settling responsible parties estimated that surface cleanup costs (removal and decontamination) were significantly less than Government estimates ($7.7 million v. $15 million). The difference in part was because some of the responsible parties would do work themselves. It remains to be seen whether the parties will be successful in meeting their advance estimates of cleanup costs. In any event, in addition to the commitment of $7.7 million in estimated cleanup costs, the Department of Justice also required as a condition of the settlement a $15 million performance bond and a judicially enforceable guarantee that the site surface cleanup would meet specified standards without regard to the estimated costs or performance bond limits. Thus, the total commitment could be in excess of $22 million. The Seymour settlement left nonsettling parties responsible for less than half the wastes at the site and potentially liable for remaining ground water cleanup (estimated at $15 million)."[79] A second group of 171 settling parties agreed to pay $3.5 million for soil and ground water cleanup.[80]

Standard of Cleanup in Superfund Actions

NCP provisions for determining the appropriate extent of remedial action at Superfund sites has been criticized by several States and environmental groups because it does not establish any specific environmental standard for the level of cleanup to be achieved, such as maximum acceptable levels of contamination. EPA's flexible approach calls for the least costly technologically feasible alternative that "effectively mitigates and minimizes damages to and provides adequate protection of public health, welfare, or the environment."[81] The NCP does not further define how the effectiveness of the alternative is to be measured or what level of protection of the public and the environment is "adequate."

EPA responded to criticisms of the NCP for not explicitly requiring that environmental standards be used in determining the appropriate extent of remedy by noting that "environmental effects and welfare concerns" are included among the criteria to be considered. Moreover, as EPA observed in the preamble to the NCP:

> In some cases, this would allow EPA to consider applicable standards in selecting the appropriate remedy. It must be noted, however, that circumstances will frequently arise in which there are no clearly applicable standards. For instance, acceptable levels of hazardous substances in soil are not established, and there are no generally acceptable levels for many other hazardous substances in other media . . .
>
> EPA cannot develop new standards for the hundreds of substances it will be confronted with in response actions. Not only is the requisite legal authority lacking in CERCLA, but such a task would also be enormous, costly, and time-consuming, and would unduly hamper the cleanup of releases, which is CERCLA's primary mandate.[82]

EPA is correct in stating that there are no established acceptable concentration levels for hundreds (if not thousands) of hazardous substances that may be found at uncontrolled hazardous waste dump sites. EPA faces a similar difficulty in setting the contaminant levels for its ground water protection strategy under the July 1982 land disposal regulations. Nevertheless, EPA has decided to use the existing maximum concentration levels for contaminants set under the Safe Drinking Water Act regulations and, where appropriate, the background contaminant levels for other substances for compliance monitoring and corrective action purposes for permitting new and existing land disposal facilities. **Under NCP, existence of contaminant levels that would require corrective action at permitted land disposal facilities under RCRA regulations could, conceivably, be allowed to continue after remedial response actions or without any remedial action being taken.**

EPA's selection of an appropriate remedy also has implications for State actions. States are required to pay a share of the costs to qualify for Superfund-financed cleanups, and the States must provide for operations and maintenance at the site for the life of the remedial action. The NCP does not specify the period of time over which a response action must be effective for controlling threats to human health or the environment from a release of hazardous substances. **Several States have expressed concern that EPA may select less expensive, incomplete remedial actions that leave the States open to substantially greater costs in the long term, instead of a more ex-**

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[79] Carol Dinkins, Assistant Attorney General, Land and Natural Resources Division, before ALI-ABA conference on Hazardous Waste, Superfund and Toxic Substances, Washington, D.C., Nov. 5, 1982.

[80] *Hazardous Waste Report*, vol. 4, Jan. 10, 1983, at 14.

[81] Preamble to the NCP, 47 F.R. 31,182, July 16, 1982.

[82] 47 F.R. 31,185, July 16, 1982.

pensive permanent remedy that removes or completely cleans up the problem caused by the hazardous substances. EPA policy statements have indicated that when the State prefers a more costly alternative, EPA will contribute only 90 percent of the total cost for the least costly alternative; the State would then pay the remaining cost of the more expensive alternative.[83]

An additional criticism raised by the States is that the NCP and the HRS do not allow States to determine which, if any, of their recommended priority sites will qualify for fund-financed remedial action. This uncertainty makes it difficult for States to plan for their own cleanup activities and to arrange for the required State contribution for Superfund actions. According to EPA officials, remedial actions at a number of priority list sites (about one-third of the initial 160 priority sites) have not been taken because States could not provide the required 10 percent contribution. **It has been estimated that as many as 42 out of 50 States may not have adequate resources for the 10 percent share of Superfund cleanup.**[84]

The Hazardous Substance Response Trust Fund—"Superfund"

Section 221 of CERCLA established the Hazardous Substance Response Trust Fund, or Superfund.[85] This fund is to be used to pay for response actions for releases of hazardous substances. Superfund will receive up to $1.38 billion from oil and chemical taxes and $220 million in appropriations authorized ($44 million in fiscal years 1981-85) to be paid in full by the end of fiscal year 1985. Additionally, the fund will receive any amounts received as reimbursements in section 107 cost-recovery actions, and any penalties or punitive damages imposed under section 107 of CERCLA. One-half of remaining funds in the trust fund established under section 311 of CWA also were transferred to the Superfund.

According to the Department of the Treasury, as of August 31, 1982, the fund had a balance of $327.4 million. Generator payments during the month were $12.6 million. Total EPA obligations from the fund from December 1980 to September 30, 1982, were $221 million.[86]

Superfund Taxes.—Title II of CERCLA, the Hazardous Substance Response Revenue Act of 1980, imposes new excise taxes on petroleum and certain chemicals. Proceeds from these taxes are deposited to the Hazardous Substance Response Trust Fund to finance response and cleanup actions. These taxes took effect on April 1, 1981, and are to continue until September 30, 1985, or until the amounts collected reach $1.38 billion, whichever occurs first.[87]

A tax of 0.79 cent per barrel is levied on crude oil received at U.S. refineries and on imported petroleum products. Exports of U.S. crude oil and domestic use of crude oil (except that used onsite for oil and gas extraction) are also subject to the tax.

A tax ranging from $0.22 to $4.87 per ton is imposed on 42 listed chemicals manufactured or produced in the United States or imported for consumption, use, or warehousing. (See table 58 for the schedule of chemical taxes.) The tax is imposed when the chemical is sold initially or used by the manufacturer, producer, or importer. Limited exclusions are provided for methane and butane burned as fuel, for certain chemicals used in fertilizer production, for sulfuric acid generated as a byproduct of air pollution control processes, and on chemicals derived from coal.

Collection of the oil and chemical taxes can be suspended if the unobligated balance in the trust funds reaches $900 million on either September 30, 1983, or September 30, 1984, and if the Secretary of the Treasury determines

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[83] 47 F.R. 31,217, July 16, 1982; 40 CFR 300.68(j).

[84] Remarks of William N. Hedeman, Director, EPA Office of Emergency and Remedial Response, Before the Senate Committee on Environment and Public Works, Feb. 15, 1983.

[85] 94 Stat. 2801, 42 U.S.C. 9631.

[86] *Hazardous Waste Report*, vol. 4, Jan. 10, 1983, at 4.

[87] See 94 Stat. 2796-99, 26 U.S.C. 2611 and 26 U.S.C. 4661; and 94 Stat. 2808, 42 U.S.C. 9653.

Table 58.—Chemical Taxes Under Superfund

In the case of:	Tax per ton
Acetylene	$4.87
Benzene	4.87
Butane	4.87
Butylene	4.87
Butadiene	4.87
Ethylene	4.87
Methane	3.44
Naphthalene	4.87
Propylene	4.87
Toluene	4.87
Xylene	4.87
Ammonia	2.64
Antimony	4.45
Antimony trioxide	3.75
Arsenic	4.45
Arsenic trioxide	3.41
Barium sulfide	2.30
Bromine	4.45
Cadmium	4.45
Chlorine	2.70
Chromium	4.45
Chromite	1.52
Potassium dichromate	1.69
Sodium dichromate	1.87
Cobalt	4.45
Cupric sulfate	1.87
Cupric oxide	3.59
Cuprous oxide	3.97
Hydrochloric acid	0.29
Hydrogen fluoride	4.23
Lead oxide	4.14
Mercury	4.45
Nickel	4.45
Phosphorus	4.45
Stannous chloride	2.85
Stannic chloride	2.12
Zinc chloride	2.22
Zinc sulfate	1.90
Potassium hydroxide	0.22
Sodium hydroxide	0.28
Sulfuric acid	0.26
Nitric acid	0.24

SOURCE: Public Law 96-510, 94 Stat. 2799, Dec. 10, 1980.

that the remaining unobligated balance in the fund will exceed $500 million on September 30 of the following year without collection of further Superfund taxes.

Uses of the Fund.—Superfund can be used to pay for Government response costs under section 104 and the NCP. The range of authorized actions and expenditures is extremely broad and includes not only activity at the site to remove or abate the danger caused by the presence of hazardous substances but also the cost of necessary investigations, testing, monitoring, engineering and design studies, and plans required to define and implement a cost effective and adequate response. The costs of pursuing cost recovery and enforcement actions against potentially responsible parties also can be paid out of the fund. Section 111(a) provides that the fund can be used to pay the necessary response costs incurred by other persons in carrying out NCP, to pay for claims approved under the review procedures of section 112, and for certain claims arising under section 304 of CWA. Additionally, the fund is specifically authorized to pay for:[88]

- the costs of assessing the amount of injury or destruction to natural resources and of the governmental effort to restore or replace natural resources injured or destroyed because of releases of hazardous substances;
- epidemiologic studies, the development and maintenance of the national registry of persons exposed to the release of hazardous substances in the environment, and diagnostic services not otherwise available to determine whether any of the exposed population are suffering from long latency diseases; and
- subject to limitations in the appropriations bills, costs of a program for enforcement and abatement action against releases, the costs of equipping, supplying, and maintaining damage assessment and response capability for strike forces and emergency response teams under NCP, and the cost of a program to protect the health and safety of workers involved in response actions.

Administrative costs or expenses that are reasonably necessary and incidental to the implementation of Superfund also may be paid out of the fund.

Liability of Responsible Parties Under CERCLA

Section 107 of CERCLA imposes far-reaching liability for response costs and damages to natural resources from releases of hazardous substances.[89] This liability applies notwithstanding any other provisions or rules of law and is subject only to the defenses in CERCLA. Prior agreements or arrangements or common law defenses that might otherwise shield a generator or facility operator from liability for releases in lawsuits by private parties may not be asserted against the Government in CERCLA cost-recovery actions.

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[88] 94 Stat. 2789; 42 U.S.C. 9611(c).
[89] 94 Stat. 2781; 42 U.S.C. 9607(a).

Whenever there are response costs due to a release or threatened release of a hazardous substance from a vessel or facility, responsible parties may be held liable for:

- all the costs of removal or remedial action incurred by the Federal or State Government not inconsistent with the NCP;
- any other necessary costs of response incurred by any other person not inconsistent with the NCP; and
- damages for injury to, destruction of, or loss of natural resources, including the reasonable costs of assessing such harm resulting from the release.

Section 107 also defines the persons who can be held liable under CERCLA. These **responsible parties** may include: the owner or operator of the facility from which there is a release or threatened release, the persons who owned or operated the facility at the time of disposal, any person who contracted or arranged with another person for disposal or treatment of hazardous substances (i.e., generators), and any person who accepted hazardous substances for transport and selected the disposal or treatment facility. Under section 107, the Government may proceed against any responsible party for the full costs incurred for response and for damages to natural resources. The extent to which one responsible party may make other responsible parties defendants in a cost-recovery action or seek contribution from them is not yet settled. The Federal Government has maintained that joint and several liability is available under CERCLA and has proceeded under this theory in several cases. Representatives of the chemical industry and other major generators, frequently targets of CERCLA cost-recovery actions for abandoned sites containing their wastes, maintain that the availability of joint and several liability under CERCLA was expressly left to the courts by Congress and has not yet been established.

Defenses.—CERCLA allows only several very narrow defenses to be raised by a responsible party who would otherwise be liable for response costs or natural resource damages. A responsible party may escape liability if it is shown by the preponderance of evidence that the release was caused **solely** by: 1) an act of God, 2) an act of war, 3) the act or omission of a third party, or 4) any combination of the previous three defenses. In raising the third party defense, the defendant must show that the third party was **not** his employee or agent or under a contractual relationship with the defendant. The defendant must also show that he "exercised due care" with respect to the hazardous substance involved and that he took precautions against foreseeable action or omissions of any such third party and the consequences that could foreseeably result from such acts or omissions.

A person who failed to notify EPA of the existence of an inactive hazardous waste site as required in section 103(c) of CERCLA may not raise any of the statutory defenses or limitations on liability in a cost recovery action.

Liability Limitations.—CERCLA limits the amount of liability that can be imposed in the event of releases of hazardous substances requiring response actions. Liability for motor vehicles, aircraft, pipelines, or rolling stock may not exceed $50 million per release or any lesser limit established by regulation, but not less than $5 million per release. (Liability for releases into navigable waters is, however, set at not more than $8 million.) For facilities (other than the classes of transportation facilities previously mentioned), the liability limit per release is set at the total of all response costs, **plus** $50 million for damages to natural resources.

The responsible party can be required to pay the full and total costs of response actions and damages to natural resources without any liability limitations if the:

- release was due to willful misconduct or willful negligence within the privity or knowledge of the responsible party;
- primary cause of the release was the violation (within the privity or knowledge of the responsible party) of applicable safety, construction, or operating standards or regulations;
- party fails or refuses to provide reasonable cooperation or assistance requested by a responsible public official in connection with response activities under the NCP; or
- party failed to notify EPA that hazardous substances had been disposed of at the facility as required by section 103(c) of CERCLA.

Punitive damages of up to three times the costs incurred by the Response Trust Fund can be assessed against a responsible party who, without sufficient cause, has failed or refused to take proper removal or remedial action in response to an administrative order under section 104 or 106 of CERCLA. These punitive damages are in addition to recovery of the response costs. A responsible party, who fails to cooperate with response actions or to comply with an abatement order, could potentially end up paying four times the original response costs.

Insurance and Contribution.—CERCLA further provides that "no indemnification, hold harmless, or similar agreement or conveyance shall be effective" to transfer liability from a potentially responsible party to another person.[90] The act, however, does not bar any agreements to ensure, hold harmless, or indemnify a party to such an agreement against any liability under section 107. A responsible party could not, therefore, escape liability, but could later invoke the benefit of an agreement to compensate him for any liability incurred. CERCLA also provides that an owner or operator or other person subject to liability under section 107 retains any cause of action for subrogation or otherwise as a result of such liability or release.

Recovery for Natural Resources Damage.—Section 107(f) provides that the United States or any State may sue to recover for injury or destruction of natural resources. Natural resources include land, air, water, fish, wildlife, and biota owned, controlled, managed, held in trust by, or appertaining to the United States, a State, local government, or a foreign government. The President (or a State), acting as trustee for the natural resources, can sue to recover damages in the amount necessary to restore or replace such resources. Damages for harm to natural resources cannot be recovered if the injury occurred before enactment of CERCLA or if: "1) the harm suffered is shown to be an irreversible and irretrievable commitment of natural resources in an environmental impact statement or other comparable analysis; 2) such impact was authorized in the decision to grant the permit or license; and 3) the facility operated in compliance with that permit or license."[91]

The Post-Closure Liability Trust Fund

Under section 107(k) of CERCLA, the liability of an owner or operator of a qualified hazardous waste facility that has been permitted under section 3005 for response costs and damages under section 107 cost-recovery action is transferred to the Post-Closure Liability Trust Fund. Liability is transferred if the owner or operator demonstrates that:

- the facility and the owner/operator has compiled with RCRA provisions and regulations regarding performance of the facility after closure; and
- the facility has been closed in compliance with the regulations and permit conditions **and** the facility and the surrounding area have been monitored for a period not exceeding 5 years after closure to demonstrate that there is not a substantial likelihood that any migration or release from confinement of any hazardous substance or other risk to public health or the environment will occur.[92]

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[90] 94 Stat. 2783; 42 U.S.C. 9607(e).

[91] 94 Stat. 2783; 42 U.S.C. 9607 (f).

[92] 94 Stat. 2784; 42 U.S.C. 9607(k).

The transfer of liability becomes effective 90 days after the facility owner or operator notifies EPA (and the State with an approved program) that it has met the requirements for transfer, unless within that time EPA (or the State) decides that the facility has not demonstrated compliance, or has submitted insufficient information.

After transfer of liability, the post-closure trust fund will assume the liability of the owner or operator under section 107 cost-recovery actions for response costs incurred and natural resource damage. Additionally, the fund may pay the costs of monitoring, care, and maintenance of a site incurred by other persons after the monitoring period required under RCRA regulations for facility closure and post-closure has expired. (For landfills, the post-closure period is 30 years.) Regulations for transfer of liability to the Post-Closure Liability Trust Fund have not yet been promulgated.

The Post-Closure Liability Trust Fund can be used for any of the same purposes as expenditures from Superfund. Additionally, the post-closure fund may be used to pay for any other claim or appropriate request for the costs of response, damage, or any other compensation for injury or loss under section 107(k) of CERCLA **or any other State or Federal law** resulting from a release of a hazardous substance at such a facility. The Post-Closure Liability Trust Fund, therefore, is potentially available to meet a broader type of claim than Superfund because of the qualification of claims payments under any other Federal or State law. Presumably this could compensate third parties for personal injuries or property damage from leaks at closed hazardous waste dump sites. In contrast, Superfund does not compensate for personal injury or property damage suffered by third parties.

Hazardous Waste Tax.—The Post-Closure Liability Trust Fund is to be financed by a tax of $2.13 per dry weight ton of hazardous wastes received at a disposal facility that is permitted or has interim status under section 3005 of RCRA. The tax is payable by the facility owner or operator. No tax is paid on any hazardous waste that will not remain at the facility after it is closed. The tax primarily affects land disposal facilities and provides an economic incentive of sorts to reduce the amount of hazardous waste sent to landfills.

Collection of the tax will begin on April 1, 1983, but will be suspended in any calendar year if, on September 30 of the preceding year, the unobligated balance in the fund exceeds $200 million. Section 303 of CERCLA provides that the authorization to collect taxes under CERCLA will expire on September 30, 1985, or whenever the total collected under the oil and chemical tax provisions reaches $1.38 billion, whichever is sooner.

Over the long term, the Post-Closure Liability Trust Fund could face substantial claims for response actions if the standards for landfills and other land disposal facilities under RCRA are not more stringent. As EPA has frequently acknowledged, all containments will eventually leak, and contaminants could reach the environment. Land disposal facilities, even with liners, final covers, and leachate collection systems, could be closed and maintain their integrity over the required 5-year monitoring period to qualify for liability transfer, and when they later begin to leak, the fund could bear the substantial response and long-term care costs. One means of preventing this is to apply a very stringent standard of proof for the required demonstration that there is no substantial likelihood of migration or release, so that few existing facilities that did not upgrade beyond minimum standards could qualify for the liability transfer.

Alternative Insurance Coverage.—Section 107(k)(4) calls for a study of the feasibility of allowing private insurance coverage as an alternative to the Post-Closure Liability Trust Fund. The Treasury was to study the feasibility and the necessary actions to make private insurance a practical and effective option to the financing arrangements in the post-closure trust fund. This study was completed in March 1982.[62] After a public hearing, the President (through

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[62] U.S. Department of the Treasury, *Hazardous Substance Liability Insurance, A Report in Compliance With Section 301(b) and Section 107(k)(4) of Public Law 96-510,* March 1982.

EPA) is to decide first whether such an alternative is feasible, and then to prescribe minimum requirements for such private coverage in lieu of participation in the Post-Closure Liability Trust Fund. If a private plan qualifies as a practical and effective alternative under the rules established, facilities enrolled in and complying with the terms of the plan will be exempt from payment of the facility tax and excluded from the liability transfer under section 107(k).

Other Federal Environmental Laws and Hazardous Waste

In enacting RCRA, Congress declared that it was closing "the last remaining loophole in environmental law, that of unregulated land disposal of discarded materials and hazardous wastes."[94] Congress further recognized that "as a result of the Clean Air Act, Water Pollution Control Act, and other Federal and State laws respecting public health and the environment, greater amounts of solid waste (in the form of sludge and other pollution treatment residues) have been created."[95] Before passage of RCRA, hazardous wastes were subject to Federal regulation only to the extent that their improper management might cause violations of other laws, such as those governing protection of public health, air quality and water quality, or those controlling the products from which the wastes were derived.

Passage of RCRA unavoidably established overlapping coverage between regulation of hazardous waste management under RCRA and regulation of environmental pollution and control of hazardous materials under other Federal laws. This potential problem of concurrent jurisdiction was recognized in RCRA section 1006(b) which requires the EPA Administrator to "integrate all provisions of this Act for purposes of administration and enforcement and to avoid duplication, to the maximum extent practicable, with the appropriate provisions of . . . (other related legislation)."[96] However, implementation of these environmental laws has resulted in very little overlap or duplicative regulatory requirements; in fact, implementation has left significant gaps in protection from the adverse effects of hazardous substances in the environment.

RCRA—Subtitle D—Regulation of Solid Waste Management

The objectives of subtitle D of RCRA are to assist in developing and encouraging methods for solid waste disposal that are environmentally sound and maximize the utilization of recovered resources, and to encourage resource conservation. These objectives are to be accomplished through State solid waste management plans prepared in accordance with guidelines published by EPA. Among other things, such a plan must describe how the State will meet the requirements of subtitle C governing hazardous waste management. States with an approved solid waste management plan are eligible for Federal technical and financial assistance. The variety of Federal technical and financial assistance mechanisms for State solid and hazardous waste management activities authorized under RCRA are discussed later in this chapter.

Section 4005(a) of subtitle D prohibits "open dumping" of solid waste.[97] To gain approval of its solid waste management plan, a State must, with EPA financial and technical assistance, conduct a survey of solid waste facilities and develop an inventory of those judged to be open dumps according to EPA-promulgated criteria (under sec. 4004(a)) that distinguish open dumps from sanitary landfills.[98] The State plan must provide for the closing or upgrading of all existing open dumps within a period not to exceed 5 years from the date of promulgation of the section 1008(a)(3) criteria. The plan must also demonstrate the State's authority to prevent the recurrence of open dumping by means of a permit program for new facilities and adequate surveillance and enforcement capabilities.

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[94] House Report 94-1491, 94th Cong., 2d sess. (1976), p. 4.

[95] RCRA, sec. 1002(b)(3), 90 Stat. 2797; 42 U.S.C. 6901 (b)(3).

[96] 42 U.S.C. 6905. The acts are the Clean Air Act, the Clean Water Act, the Federal Insecticide, Fungicide and Rodenticide Act, the Safe Drinking Water Act, and the Marine Protection, Research, and Sanctuaries Act.

[97] 42 U.S.C. 6945.

[98] 40 CFR Part 257 (1982).

Enforcement of the ban on open dumping is largely in the hands of each State. However, solid waste activities are covered by the section 7002 citizen suit provision and section 7003 imminent hazard authority of RCRA.

Many existing "open dumps" and approved sanitary or municipal landfills contain hazardous wastes that were deposited there either before the subtitle C regulations took effect or because the wastes were not regulated under the subtitle C regulatory program (e.g., hazardous wastes produced by small-quantity generators).

In practice, implementation of the subtitle D provisions has been incomplete. Most, but not all, States have prepared a first round of solid waste management plans, many of which have received EPA approval. Partial inventories of open dumps have been prepared by the States and published in the Federal Register. Virtually all Federal financial and technical assistance under subtitle D for State solid waste plans has been terminated. The fiscal year 1983 appropriations, however, include funds to support the site inventory needed to complement efforts under the hazardous waste and Superfund programs.

Hazardous Materials Transportation Act (HMTA)[189]

HMTA authorizes DOT to establish regulations governing the transport of hazardous materials, including wastes. Under HMTA "hazardous materials" are those that the Secretary determines may pose an unreasonable risk to health and safety or property when transported in commerce. DOT regulations provide for the classification of hazardous materials, disclosure requirements, shipping container requirements, labeling and placarding standards, handling procedures for various modes of transport, and reporting of accidents.[190]

In carrying out its responsibilities under RCRA Subtitle C, EPA has adopted these same regulations to ensure consistency between the requirements of the two agencies as required by section 3003(b) of RCRA. The section also authorizes the EPA Administrator to make recommendations to the Secretary of Transportation on hazardous waste regulations under HMTA and on the addition of materials to be covered by that act.

Although RCRA requires maximum consistency between the regulations of DOT and EPA, each agency still retains separate authority to promulgate and enforce its own regulations.

Toxic Substances Control Act (TSCA)[191]

TSCA directs EPA to inventory all chemical substances in commerce, to require premanufacture notice of all new chemical substances, to gather available information about the toxicities of particular chemicals and exposures, to require industry testing under certain circumstances where data are insufficient, and to assess whether unreasonable risks to human health or the environment are involved. In determining whether a substance poses an unreasonable risk, EPA must consider such factors as: type of effect (e.g., chronic or acute, reversible or irreversible); degree of risk; characteristics and numbers of humans, plants, animals, or ecosystems at risk; amount of knowledge about the effects; availability of alternative substances and their expected effects; magnitude of the social and economic costs and benefits of possible control actions; and appropriateness and effectiveness of TSCA as the legal instrument for controlling the risk.

EPA may prohibit, limit, or control the manufacture, processing, distribution through commerce, use, and disposal of substances posing an unreasonable risk. These measures can range from requiring hazard-warning labels to banning the manufacture or use of an especially hazardous substance.[192]

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[189] 49 U.S.C. 1801 et seq.

[190] 49 CFR Parts 171-179 (1982).

[191] Public Law 94-469, 90 Stat. 2003 (1976); 15 U.S.C. 2601 et seq.

[192] TSCA, sec. 6, 90 Stat. 2020; 15 U.S.C. 2605.

Regulations under TSCA have been issued for two groups of chemicals: polychlorinated biphenyls (PCBs) and certain chlorofluorocarbons (CFCs). The manufacture of PCBs has been prohibited, except as allowed by EPA. Rules governing the use and disposal of PCBs in a variety of applications have been established. However, the disposal of about 40 percent of the PCBs still in use (largely contained in small appliances and capacitors) has not been regulated under TSCA. Some, but not all, uses of CFCs have been prohibited. In general, the standards for treatment and disposal of PCBs under TSCA are more stringent than the standards for hazardous waste under RCRA. For example, under TSCA rules, incinerators burning liquid PCBs must attain a 99.9999 percent destruction level; RCRA standards are only 99.99 percent.[103]

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)[104]

FIFRA requires that all pesticides be registered with EPA on the basis of submitted safety data, and prohibits the sale, distribution, and use of pesticides except in accordance with registered labels. To obtain registration, it must be demonstrated, among other things, that a pesticide, when used in accordance with widespread and commonly recognized practice, will not generally cause "unreasonable adverse effects on the environment." The EPA Administrator is required, after consultation with other interested Federal agencies, to establish procedures and regulations for the disposal or storage of packages and containers of pesticides.

Subject to trade secret exclusions, the EPA Administrator must make public the data called for in the registration statement of a pesticide. Information obtained through FIFRA reporting and testing programs may be useful in establishing whether a discarded pesticide should be classified as an RCRA hazardous waste.

Clean Water Act (CWA)[105]

The overall objective of CWA is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Among the goals and policies used to promote this objective are those of eliminating the discharge of pollutants into navigable waters by 1985 and prohibiting the discharge of toxic pollutants in toxic amounts.

Section 301(a) prohibits the discharge of any pollutant from a point source without a permit under section 402 (which establishes the National Pollutant Discharge Elimination System (NPDES)), and except in conformance with technology-based effluent limitations under section 301, water quality-related effluent limitations under section 302, new source performance standards under section 306, and toxic and pretreatment effluent standards under section 307.[106]

Technology-based limitations are tied to three categories of discharges—municipal, industrial, and toxic. Industrial discharges have been subdivided into conventional pollutants (biological oxygen demand, suspended solids, fecal coliform, pH, oil and grease), toxic (included on a list of toxic substances), and nonconventional pollutants (other than conventional or toxic).

The 1972 amendments provided for the listing of toxic pollutants based on factors such as toxicity, persistence, degradability, potential for exposure of organisms, etc. Toxic pollutant effluent standards providing an "ample margin of safety" were to be promulgated on a pollutant-by-pollutant basis.[107] Because of difficulties and delays in the implementation of this provision, and prompted by a court settlement, the 1977 amendments call for EPA to develop and issue "best available technology" effluent limitation guidelines, pretreatment standards, and new source performance standards for 21 major industries covering 65 serious pollutants or groups of pollutants (see table 59).

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[103] 40 CFR 761.70. TSCA, sec. 6(e), directs EPA to prescribe methods for the disposal of PCBs, 15 U.S.C. 2605(e).

[104] 7 U.S.C. 135 et seq.

[105] 33 U.S.C. 1251 et seq.

[106] 33 U.S.C. 1311.

[107] 33 U.S.C. 1317(a)(4).

Table 59.—Toxic Water Pollutants Under Section 307 of the Clean Water Act

Classes of toxic pollutants for which EPA must issue water quality criteria

1. Acenaphthene
2. Acrolein
3. Acrylonitrile
4. Aldrin/dieldrin
5. Antimony and compounds
6. Arsenic and compounds
7. Asbestos
8. Benzene
9. Benzidine
10. Beryllium and compounds
11. Cadmium and compounds
12. Carbon tetrachloride
13. Chlordane (technical mixture and metabolites)
14. Chlorinated benzenes (other than dichlorobenzenes)
15. Chlorinated ethanes (including 1,2-dichloroethane, 1,1,1-trichloroethane, and hexachloroethane)
16. Chloroalkyl ethers (chloromethyl, and mixed ethers)
17. Chlorinated naphthalene
18. Chlorinated phenols (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)
19. Chloroform
20. 2-Chlorophenol
21. Chromium and compounds
22. Copper and compounds
23. Cyanides
24. DDT and metabolites
25. Dichlorobenzenes (1,2-, 1,3-, and 1,4-dichlorobenzenes
26. Dichlorobenzidine
27. Dichloroethylenes (1,1- and 1,2-dichloroethylene)
28. 2,4-Dichlorophenol
29. Dichloropropane and dichloropropene
30. 2,4-Dimethylphenol

3 . Dinitrotoluene

32. Diphenylhydrazine
33. Endosulfan and metabolites
34. Endrin and metabolites
35. Ethylbenzene
36. Fluoranthene
37. Haloethers (other than those listed elsewhere; includes chlorophenylphenyl esters, bromophenylphenyl ether, bis(dichloroisopropyl) ether, bis(chloroethoxy) methane, and polychlorinated diphenyl ethers)
38. Halomethanes (other than those listed elsewhere; includes methylene chloride, methyl chloride, methyl bromide, bromoform, dichlorobromomethane, trichlorofluoromethane, dichlorodifluoromethane)
39. Heptachlor and metabolites
40. Hexachlorobutadiene
41. Hexachlorocyclohexane (all isomers)
42. Hexachlorocyclopentadiene
43. Isophorone
44. Lead and compounds
45. Mercury and compounds
46. Naphthalene
47. Nickel and compounds
48. Nitrobenzene
49. Nitrophenols (including 2,4-dinitrophenol, dinitrocresol)
50. Nitrosamines
51. Pentachlorophenol
52. Phenol
53. Phthalate esters
54. Polychlorinated biphenyls (PCBs)
55. Polynuclear aromatic hydrocarbons (including benzanthracenes, benzopyrenes, benzofluoranthene, chrysenes, dibenzanthracenes, and indenopyrenes)
56. Selenium and compounds
57. Silver and compounds
58. 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)
59. Tetrachloroethylene
60. Thallium and compounds
61. Toluene
62. Toxaphene
63. Trichloroethylene
64. Vinyl chloride
65. Zinc and compounds

SOURCE: 43 F. R. 4108, Jan. 31, 1978.

The list of industries, however, is not identical to the list of generators under RCRA, and the range of pollutants of concern under RCRA is much broader. The EPA Administrator has some discretion in adding to or removing pollutants from the list of pollutants, taking into account the same factors used in preparing the list initially. The Administrator may also issue a more stringent toxic pollutant effluent standard if appropriate.

In relation to toxic and hazardous materials that might enter the environment other than through effluent discharge, EPA is authorized to establish "best management practices" to be implemented as provisions of NPDES permits, for control of plant site runoff, leaks, spills, sludge, waste disposal, and drainage from raw material storage sites.

CWA requires promulgation of standards for the pretreatment of industrial pollutants discharged to publicly owned treatment works (POTWs) that might create problems in sewers (fire, corrosion, explosion), inhibit municipal sewage treatment processes, or pass untreated into waterways or the POTWs sludge, thereby rendering it unfit for beneficial use or disposal.[108] However, subject to State and EPA approval, a municipality may provide at least partial treatment for industrial toxic wastes in a way which allows the industry to reduce its pretreatment costs. (Hazardous waste discharged into a POTW is currently excluded from the definition of hazardous waste and regulation under RCRA because of the CWA pretreatment provision.)

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[108] 33 U.S.C. 1317(b).

Implementation of the pretreatment requirements has been subject to some delay. Amendments to the general regulations (originally promulgated in 1978) were promulgated in 1981, then suspended by the Reagan administration pending regulatory impact analysis, and later made partially effective following court action. Certain provisions remain suspended. EPA is currently considering further changes, generally involving greater local control and responsibility for pretreatment requirements, as well as a decreased emphasis on mandatory national technology-based categorical standards.[109]

EPA has ruled that any nondomestic waste mixed with domestic waste in a sewer system leading to a POTW is not a solid waste. If this nondomestic waste is not treated because of the lack of pretreatment standards or because the generator is not regulated under CWA, the discharge into the POTW could be regulated under subtitle C as a hazardous waste activity if a hazardous waste (as defined in RCRA) is involved. Furthermore, although a point source discharge covered by a NPDES permit is not subject to subtitle C regulation, any waste management activity occurring before the flow reaches the point of discharge may be subject to subtitle C regulation if a hazardous waste is involved.

Section 311 establishes procedures by which EPA can act to prevent or respond to spills and other nonroutine releases of oil and hazardous substances into U.S. waters and can recover the mitigation costs from the discharger. EPA was required to prepare a national contingency plan (NCP) for oil and chemical and to establish a special fund for emergency assistance to persons and communities in cases of pollutant and contaminant discharges. The program is not limited to water pollution emergencies, but covers "all releases to the environment." The NCP established under CWA was expanded by CERCLA to include a comprehensive national hazardous substance response plan to deal with chemical spills and releases of hazardous substances into the environment.

Safe Drinking Water Act (SDWA)[110]

SDWA provides for EPA to establish national primary drinking water quality standards and, as needed, to require application of specific water treatment technologies. The act regulates both public and private water utilities serving from a few dozen to millions of people. The primary standards, or "maximum contaminant levels," are intended to protect human health. EPA may also recommend secondary standards for substances that do not threaten public health but that cause aesthetic problems with the odor, or appearance affecting the usability of water. The SDWA gives the main responsibility for enforcing the standards to the States. Each State must adopt standards at least as strict as the national standards, and must be able to monitor and enforce compliance with the standards by individual supply systems. If a State cannot or does not carry out these responsibilites, EPA can conduct the program itself.

Maximum contaminant levels (MCLs) have been established to date for 10 inorganic chemicals (arsenic, barium, cadmium, chromium, fluoride, lead, mercury, nitrate, selenium, and silver), 6 pesticides (toxaphene, methoxychlor, endrin, lindane, 2,4-D, and 2,4,5-T), and trihalomethanes (which result primarily from reactions between natural organic chemicals present in raw water and the chlorine typically used as a disinfectant). Maximum levels for bacterial contamination, radioactivity, and turbidity have also been established (see table 60).[111] For a few compounds, interim nonbinding guidelines (Suggested No Adverse Response Level—"SNARL"—documents) have

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[109] See 47 F.R. 4,518, Feb. 1, 1982, 40 CFR Part 403, originally published at 46 F.R. 9,404, Jan. 28, 1981.

[110] 42 U.S.C. 300f-300j.

[111] 40 CFR 141, subpart B (1982).

Table 60.—National Interim Primary Drinking Water Standards

Constituent	Maximum concentration (in mg/l unless specified)
Inorganic chemicals	0.05
Arsenic	0.05
Barium	1
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10
Selenium	0.01
Silver	0.05
Fluoride	1.4-2.4
Turbidity	1 tu up to 5 tu
Coliform bacteria	1/100 m-(mean)
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4-D	0.1
2,4,5-TP Silvex	0.01
Total trihalomethanes	0.1
Radionuclides:	
Radium 226 and 228 (combined	5 pCi/l
Gross alpha particle activity	15 pCi/l
Gross beta particle activity	4 mrem/year

SOURCE: 40 C.F.R. 141 (1982)

been prepared for use by States and municipalities on a case-by-case advisory basis. MCLs established under SDWA will provide part of the basis for the ground water protection strategy adopted in the July 1982 land disposal standards under RCRA.

SDWA also provides for a program regulating the underground injection of wastes and other materials. Injection wells are a widely used method of industrial waste disposal. EPA is required to list States that are thought to require underground injection control (UIC) programs and to set minimum national requirements for such programs. EPA must approve the adequacy of each proposd UIC program, although the agency is specifically instructed not to disrupt unnecessarily any State programs already being effectively enforced. Where an adequate program is not being carried out by a State, however, EPA will administer the program.

Regulations promulgated by EPA in 1980 distinguish five different kinds of wells: deep waste-disposal wells (or those below usable aquifers), wells related to oil and gas production, wells for special processes such as solution mining and geothermal energy, shallow wells (or those injecting into usable aquifers) for hazardous waste disposal, and all others. Following the settlement of legal challenges to these regulations, EPA promulgated revised regulations in February 1982.[112] Standards have not yet been promulgated for wells in which waste is injected above underground sources of drinking water (see ch. 5), nor have standards been implemented in many jurisdictions in which waste is injected directly into underground sources of drinking water.

SDWA provides for controls over the underground injection of wastes. RCRA also authorizes regulation of hazardous waste disposal by injection into or onto the land or waters so that wastes might enter the environment. Because of this overlapping jurisdiction, EPA has promulgated a permit-by-rule approach for injection wells in the RCRA subtitle C program. The owner or operator of an injection well disposing of hazardous waste will be deemed to have a RCRA permit if he: 1) obtains and complies with UIC permit, and 2) complies with special requirements under SDWA for wells injecting hazardous waste.

In general, the UIC program requires that high-risk types of wells must be authorized by permits before they may be operated, while lower-risk wells may be operated without individual permits under general rules. Where needed, UIC permits impose both technological and administrative requirements on well operators. UIC permit conditions generally cover construction, operation, monitoring, reporting, special corrective actions, well abandonment, Government access to operator records and facilities, and provisions for permit review, modification, and termination.

SDWA also contains an important provision for protection of aquifers that supply drinking water. SDWA prevents the use of Federal assistance for purposes that could endanger irreplaceable drinking water supplies. It applies where EPA (on its own initiative or on receiving a petition from the affected community) determines that an area has an aquifer which is its sole or principal drinking water source.[113] If contamination of such an aquifer will cause a significant health hazard, EPA may delay or stop commitment of Federal assistance for any projects or activities that could cause such contamination. By 1980, seven "sole source aquifers" had been designated.

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[112] 47 F.R. 4,992, Feb. 3, 1982; to be codified at 40 CFR part 146.

Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA)[114]

Enacted to implement international treaty obligations restricting ocean dumping, MPRSA has the purpose of preventing or severely limiting the ocean dumping of any material that would adversely affect human health, welfare, or amenities, or the marine environment, ecological system, or economic potentialities. Practically, the act requires stopping all "harmful dumping" in the oceans by 1981. The critical phrase "harmful dumping" is defined as the dumping of wastes that do not meet certain environmental impact criteria;[115] such wastes are likely to include all hazardous wastes as defined under RCRA. A 1977 amendment to the act specifies that the ocean dumping of sewage sludge must cease by 1981.

MPRSA directs EPA and the U.S. Army Corps of Engineers (subject to EPA review) to administer permit systems to control dumping. The permit responsibilities of the Corps are limited to dumping of dredged materials.

The ocean dumping of municipal sewage sludge increased between 1973 and 1978, possibly reflecting implementation of CWA and the resulting growth in the generation of sludge. Ocean dumping of industrial wastes declined during the same period, but increased pressure to allow more such dumping might be expected following implementation of the full RCRA regulatory scheme. (See discussion of ocean dumping in ch. 5.)

Clean Air Act (CAA)[116]

CAA requires EPA to establish national ambient air quality goals designed to protect public health and welfare, and to take action (if State and local governments will not) to see that the goals are met. For the major pollutants (currently including sulfur dioxide, carbon monoxide, nitrogen oxides, nonmethane hydrocarbons, particulates, ozone, and lead), the EPA has set primary and secondary National Ambient Air Quality Standards (NAAQS). The primary standards are designed to protect public health (with an adequate margin of safety from adverse health effects). Secondary standards designed to protect public welfare such as protection of plants and animals, buildings and materials, and visibility from the adverse affects of pollutants have also been established. The States are required to submit State implementation plans with emission limitations and other measures necessary to achieve and maintain the NAAQS within the deadlines established by Congress. If a State either does not submit a plan or does not receive EPA's approval of its plan, EPA itself is required to take the necessary actions to attain and maintain the standards in that State.

CAA provides for the establishment of national emission standards applicable to certain major new and modified industrial sources. The States are required to establish emission standards applicable to existing industrial sources. In areas that do not meet one or more of the NAAQS (nonattainment areas), and in areas subject to nondegradation controls, major stationary sources must obtain a permit and must meet stringent new source performance standards.

Section 112 of the act provides for the establishment of national emission standards for "hazardous air pollutants" for which there is no applicable ambient air quality standard.[117] EPA may designate as "hazardous" any pollutant which "may cause, or contribute to, an increase in mortality or serious irreversible, or incapacitating reversible, illness." Within 1 year of listing a hazardous pollutant, EPA is to issue standards for controlling hazardous pollutant emissions. The resulting standards must provide an "ample margin of safety to protect the public health." Where an emission standard is not feasible, EPA may prescribe a design, equipment, work practice, or operational standard.

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[113] 42 U.S.C. 300h-3. Regulations are found at 40 CFR 1464 (1982).

[114] 33 U.S.C. 1401 et seq.

[115] 40 CFR 227, subpart B (1982).

[116] 42 U.S.C. 7401 et seq.

[117] 42 U.S.C. 7412.

For stationary sources about to be built or modified, hazardous pollutant standards become effective immediately upon proposal. EPA has the authority to prohibit the construction or modification of any source that will not comply with promulgated standards. Existing sources must comply within 90 days of promulgation of final standards unless a waiver is granted.

To date, EPA has listed and set final standards under section 112 for four substances: beryllium, mercury, asbestos, and vinyl chloride (see table 61).[118] Three other substances have been listed as hazardous, but final standards have not yet been issued: for benzene, standards have been proposed; for arsenic, they are under development; and for radionuclides they are under consideration. EPA has been sued for its failure to meet the 1-year deadline for promulgating standards for these substances. Among other pollutants that have been considered for listing under section 112 are: coke oven emissions, polycyclic organic matter, cadmium, ethylene dichloride, perchloroethylene, acrylonitrile, methylene chloride, methyl chloroform, toluene, and trichloroethylene.[119]

Table 61.—Hazardous Air Pollutants Under Section 112 of the Clean Air Act

Listed pollutants	Major source categories	Regulation status
Status of toxic air pollutants regulation		
Asbestos	Mills, manufacturing, demolition	Promulgated
Beryllium	Extraction plants, foundries, machine shops	Promulgated
Mercury	Smelters, chlor-alkali, sludge incineration	Promulgated
Vinyl chloride	Manufacture, polymerization	Promulgated
Benzene[a]	Chemicals and petroleum	Proposed
Arsenic[b]	Copper smelter	Under development
Radionuclides[c]	Uranium mines, phosphoric acid plants	Under consideration[d]
Chemicals under assessment		
Acetaldehyde	Hexachlorocyclopentadiene	
Acrolein	Maleic anhydride	
Acrylonitrile	Manganese	
Allyl chloride	Methyl chloroform	
Benzyl chloride	(1,1,1 trichloroethane)	
Beryllium	Methylene chloride	
Cadmium	(dichloronmethane)	
Carbon tetrachloride	Nickel	
Chlorobenzene	Nitrobenzene	
Chloroform	Nitrosomorpholine	
Chloroprene	Perchloroethylene	
Coke oven emissions	Phenol	
o-,m-,p- cresol	Phosgene	
p-Dichlorobenzene	Polychlorinated biphenyls	
Dimethyl nitrosamine	Propylene oxide	
Dioxin	Toluene	
Epichlorohydrin	Trichloroethylene	
Ethylene dichloride	Vinylidene chloride	
Ethylene oxide	o-,m-,p-xylene	
Formaldehyde		

[a] No standards yet issued.

[b] No standards yet issued. EPA has been sued for failure to promulgate standards within statutory deadline. Settlement in negotiation.

[c] No standards yet issued. EPA was sued by the Sierra Club (and others) for failure to promulgate standards within statutory period. EPA now under court order to issue proposed rules.

[d] Sources to be regulated not yet determined.

SOURCE: *Hearings on Oversight on the Clean Air Act*, Senate Committee on Environment and Public Works, 97th Cong., 1st sess., June 1981, pp. 560-561.

Air pollutants from hazardous waste facilities—or from the burning of hazardous waste for energy recovery—might in principle be controlled under either section 112 of CAA or subtitle C of RCRA. However, the pollutant-by-pollutant approach under CAA is cumbersome. Only a few pollutants have been listed and standards have been established for only a very narrow group of facilities. The RCRA program is better suited for the control of pollutants from hazardous waste TSDFs, while other specific airborne hazardous pollutants generated in a range of industrial processes might be more readily controlled using section 112 standards.

Air pollution controls have themselves resulted in some increase in the generation of hazardous waste. However, as mentioned elsewhere, fly ash waste and flue gas emission control waste generated primarily from the combustion of coal or other fossil fuels have temporarily been excluded from regulation under subtitle C of RCRA, pending completion of studies required by 1980 RCRA amendments.

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[118] 40 CFR Part 61.

[119] In 1979, EPA proposed a general methodology which was intended for use in identifying, assessing, and regulating suspected carcinogens that are emitted from stationary sources. The proposal includes the listing under section 112 of any air pollutant determined to present a significant carcinogenic risk to human health as the result of emissions from one or more categories of stationary sources. This listing would be accompanied, when applicable, by the proposing of generic emission standards for source categories producing or handling significant quantities of the substance. Final standards would, at a minimum, require sources to use best available technology to reduce emissions, as well as additional measures (including the closure of certain sources) as necessary to reduce any remaining risk deemed to be unreasonable. Further action on the airborne carcinogen policy has been deferred by EPA. 44 F.R. 58,642, Oct. 10, 1979.

Surface Mining Control and Reclamation Act of 1977 (SMCRA)[120]

SMCRA establishes a nationwide program to protect society and the environment from the adverse effects of coal mining. Regulations issued under the act by the Department of the Interior cover three major areas:

- performance standards for protection of the environment and public health and safety, permit applications, and bonding requirements for surface coal mining and reclamation operations;
- procedures for preparation, submission, and approval of State programs to control mining and reclamation; and
- development and implementation of a Federal program for any State that does not develop an acceptable program.

The surface mining regulatory program includes standards and requirements for protection of surface and ground waters from contamination from mining wastes and overburden. Section 1006(c) of RCRA provides for integration between RCRA and SMCRA in controlling solid and hazardous wastes and requires consultation between EPA and the Department of the Interior on the adequacy of these rules.[121] The Secretary of the Interior is given exclusive responsibility for carrying out the requirements of RCRA subtitle C with respect to coal mining wastes or overburden for which a permit under SMCRA has been issued or approved. Section 3005(f) of RCRA states that a permit issued or approved under SMCRA covering any coal mining wastes or overburden shall be deemed to be a treatment, storage, and disposal permit issued under RCRA.[122] Subtitle C regulations are not be applicable to the treatment, storage, or disposal of coal mining wastes and overburden covered by such a permit.

Nonregulatory Approaches and Technical Support

RCRA and other laws contain nonregulatory provisions (i.e., which do not directly require compliance with standards or controls) that are intended to influence hazardous waste management activities by State and local governments and the private sector. These provisions include direct or indirect incentives to adopt State programs or to develop alternative hazardous waste management practices. Among the existing provisions are those that provide for financial and technical assistance to States, information distribution, research and development activities, and interstate cooperation. Although, RCRA authorizes a broad range of non-regulatory activities that could promote the adoption of better waste management strategies by State and private industry, these measures have been largeley ineffective due to lack of adequate funding and/or failure of implementation by Executive agencies.

Interstate Cooperation.—Section 1005 of RCRA[123] allows two or more States to establish agreements or compacts, not in conflict with any U.S. law or treaty, for cooperative effort and mutual assistance in the management of solids and/or hazardous waste. These regional compacts allow States to plan for regional waste needs and develop consistent regulatory policies.

Guidelines for Solid Waste Management.—Section 1008[124] of RCRA requires the EPA Administrator to develop and publish suggested guidelines for solid waste management which will establish criteria for defining solid waste and will provide a technical and economic description of the level of performance in protecting health and the environment attainable by available solid waste management practices.

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[120] Public Law 95-87, 91 Stat. 445, Aug. 3, 1977; 30 U.S.C. 1201 et seq.

[121] 42 U.S.C. 9605, as amended by the Solid Waste Disposal Act Amendments of 1980, Public Law 96-482, sec. 2, 94 Stat. 2334.

[122] 42 U.S.C. 9625(f), as amended by Public Law 96-482, sec. 11, 94 Stat. 2338.

[123] 42 U.S.C. 6904.

[124] 42 U.S.C. 6907.

Where appropriate, the guidelines are also to include information for use in deciding the adequate location, design, and construction of solid waste management facilities, including consideration of regional, geographic, demographic, and climatic factors.

Several solid waste guidelines were issued by EPA under section 209 of SWDA before passage of RCRA.[125] Since then, EPA's guideline-writing under RCRA section 1008 has been minimal. The minimum criteria for use in defining practices that constitute open dumping were issued not as a separate guideline document but rather in combination with criteria for classifying facilities as sanitary landfills or open dumps, required by section 4004(a) of RCRA.[126]

Section 6004 of RCRA provides that any guidelines issued under section 1008 are binding on executive agencies and units of the legislative branch of the Federal Government.[127]

Financial Assistance.—Section 3011 of RCRA authorizes Federal grants to assist the States in the development and implementation of hazardous waste management programs.[128] EPA has determined that these grants are also available for States with partial authorization or cooperative arrangements. Hazardous waste grants have steadily increased as shown in table 7 in the following section. Because the subtitle C hazardous waste regulatory program has only recently been promulgated in reasonably complete and final form, and because the development, final authorization, and implementation of State hazardous waste programs entail a major effort yet to be completed, EPA has been widely criticized for failing to request or provide sufficient financial assistance to the States at a time when their regulatory responsibilities under RCRA will increase dramatically. EPA has recently suggested that the State grants program be phased out and that States finance their regulatory programs through increased fees and State appropriations.[129]

Under section 3012,[129] grants may be made to the States for a continuing program to inventory active and inactive hazardous waste sites. In fiscal year 1983, Congress appropriated $10 million from Superfund to carry out this program. EPA had not previously requested such funds.

Under subtitle D, section 2007, 4007, and 4008 of RCRA provide for EPA to grant financial assistance to States and sub-State agencies for the purpose of developing and implementing their solid waste plans.[130]

Under section 4008(a)(2)(A), financial assistance may be provided for facility planning and feasibility studies; expert consultation; technology assessments; legal expenses; construction feasibility studies; and fiscal or economic investigations or studies, but it may not include construction or land aquisition.[131] Applicants for such assistance must agree to comply (with respect to the project or program assisted) with the requirement under section 4005 for the closing or upgrading of open dumps and with the requirements of the subtitle C hazardous waste program, as well as agreeing to apply practices, methods, and levels of control consistent with any guidelines issued under section 1008.[132]

Provisions for financial assistance under subtitle D generally emphasize support for resource conservation and recovery; indeed, assistance provided under section 4008(a)(3) is restricted to uses related to energy and materials conservation and recovery as described in section 4003(b)(1).[133] The primary emphasis is on conservation and recovery in relation to municipal waste, but section 4003(b)(2) refers also to "other sources of solid waste from which energy and materials may be recovered or minimized" which could, in principle, include hazardous waste.

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[125] Public Law 89-272, 79 Stat. 997 (1965).

[126] 42 U.S.C. 6944.

[127] 42 U.S.C. 6931.

[128] 42 U.S.C. 6931.

[129] 42 U.S.C. 6933, as amended by Public Law 96-482, sec. 17, 94 Stat. 2344 (1980).

[130] Section 2007, as amended, provides for general authorizations for appropriations for RCRA implementation and provides that specified shares are to be allocated to the Resource Recovery and Conservation Panels, (20 percent or $5 million), to the Hazardous Waste Regulatory Program (30 percent, excluding sec. 3011 grants to States); and to sec. 4008 programs for State, local, and regional agencies resource and material conservation and recovery programs and State solid waste plans (25 percent of total appropriated for sec. 4008 programs).

[131] 42 U.S.C. 6848.

[132] 42 U.S.C. 6945.

In practice, EPA provided grants under subtitle D (including grants specifically in support of resource recovery) totaling $27,910,000 in fiscal year 1980 and $12,936,000 in fiscal year 1981. However, these grants were phased out at the end of fiscal year 1981, although recipients were permitted to spend in fiscal year 1982 any money that previously had been allocated but remained unspent. The phaseout left States without Federal support for, among other things, continued solid waste planning and continued preparation of the inventory of open dumps, as well as for plan implementation.

Technical Assistance.—Under subtitle D, section 4008(d) authorizes EPA to provide technical assistance to State and local governments for developing and implementing State plans.[134] Technical assistance on resource conservation and recovery (in practice, largely applied to municipal waste) may be provided through "Resource Recovery and Conservation Panels." These are teams of personnel, including Federal, State, and local employees or contractors who supply assistance at no charge to States and local governments.[135]

The delivery of technical assistance was funded at the level of $4,304,000 in fiscal year 1980 and $3,198,000 in fiscal year 1981 but was eliminated in fiscal year 1982 EPA budget.

RCRA also directed the Department of Commerce to provide technical support to encourage the commercialization of proven technologies for resource conservation and recovery. The National Bureau of Standards was directed to publish guidelines for specifications for classifying materials recovered from wastes. The Department of Energy was given the responsibility for R&D programs for recovery of synthetic fuels from solid wastes. EPA was directed to coordinate and consult with DOE on other energy related solid waste programs.

Research and Development.—Subtitle H, section 8001, of RCRA authorizes EPA to conduct or assist others in conducting research, investigations, experiments, training, demonstrations, surveys, public education programs, and studies on various aspects of solid and hazardous waste management.[136] Among the possible areas for research and development activities authorized under this section are: adverse health and environmental effects of solid and hazardous waste, financing and operation of waste management programs, development of solid and hazardous waste management technologies, resource conservation and recycling technologies, and waste reduction techniques.

Section 8002 directs the EPA Administrator to carry out a number of special studies including an assessment of the adverse environmental effects of solid waste from surface and underground mines and the generation and management of sludge.[137] Section 8002 also describes the study required under the 1980 amendments to section 3001 for an assessment of environmental and health effects of disposal of hazardous waste from oil, gas, and geothermal energy exploration, development and production, from burning of coal and fossil fuels, from mining and processing of ores and minerals, and from cement kiln dust.

Other agencies also carry out related R&D activities, such as the National Institute of Health (screening and testing of carcinogenic, mutagenic, terotogenic effects of chemicals), the Occupational Safety and Health Administration and National Institute for Occupational Safety and Health (protection of health and safety of employees working in both industrial and cleanup environments). The National Science Foundation has in the past funded major R&D projects related to toxic chemicals and hazardous waste management.

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[133] 42 U.S.C. 6943(b)(1).
[134] 42 U.S.C. 6948(d).
[135] 42 U.S.C. 6913.
[136] 42 U.S.C. 6981.
[137] 42 U.S.C. 6982.

EPA Research Activities in Hazardous Waste

All research activities within EPA are the responsibility of the Office of Research and Development (ORD).[138] ORD has defined the following five objectives to provide support to the RCRA hazardous waste program:

1. **Waste analysis and characterization:** development of analytical methods and procedures for the detection and identification of substances. development of monitoring guidelines, and a quality assurance program for development and enforcement of regulations.
2. **Control technology:** assessment of disposal and treatment technologies, development and evaluation of technologies for remedial actions, and assistance of the Office of Solid Waste in reviewing permit applications.
3. **Risk assessment:** development of data and methodologies for determining risks to human health and environment.
4. **Spills response:** development of methods and guidelines to provide quick response to emergency spills.
5. **Long-term research:** investigation of advanced technologies.

Since 1981, there has been a significant shift of emphasis within ORD from longer term research projects (e.g., studies of the effects of chemicals and new process developments) to programs which directly support the promulgation of regulations. Some 15 to 20 percent of ORD's total budget is set aside for exploratory research projects; however, little of a truly exploratory or long-range nature is being done even in this portion of the program.

OTA has reviewed current research projects planned for completion by 1986 (see table 62). Major emphasis has been placed on risk assessments and analytical methods for detection and measurement of specific chemicals. The control technologies emphasized are landfills and land treatments. Research plans for incineration focus on the development of performance standards for hazardous waste incinerators, not the improvement in incinerator technology. The investigation of new treatment technologies has been omitted even in the long-term research strategy planning.

ORD's research in support of the toxic substances program under TSCA and the Superfund program under CERCLA may also contribute to the management of hazardous waste. Again, the emphasis appears to have shifted toward relatively short-term research directed at problems of immediate regulatory concern.

Collection and Dissemination of Information.—Under subtitle H, section 8003 of RCRA directs the EPA Administrator to develop, collect, evaluate, and coordinate information on a variety of aspects of solid and hazardous waste management.[139] A program for the rapid dissemination of information on solid waste management, hazardous waste management, resource conservation, and methods of resource recovery from solid waste is to be implemented.

The Administrator is also directed to establish and maintain a central reference library. Information in this library, to the extent practicable, is to be collated, analyzed, verified, and published, and made available to State and local governments and other persons. Additionally, the Administrator is to develop and publish a model cost and revenue accounting system, and to recommend model codes, ordinances, and statutes providing for sound solid waste management.

Until 1981, EPA maintained a solid waste technical information service in Cincinnati, Ohio, which distributed free copies of EPA solid waste reports. Relatively technical documents (e.g., EPA contractors' reports) were frequently omitted from this collection but could be obtained for a charge from the National Technical Information Service (NTIS). The service in Cincinnati has been discontinued, and only a very small number of copies of EPA reports are typically made available by

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[138] Information on research activities of EPA/ORD was obtained by OTA from ORD in spring-summer of 1982 and from EPA's fiscal year 1983 Budget Justification.

[139] 42 U.S.C. 6983.

Table 62.—Research Projects Planned by ORD in Support of Hazardous Waste Management Program

Risk assessment	Control technology	Waste analysis	Long-term research	Spills response
• Integrate existing risk assessment methods into guidelines • Develop predictive methods for assessing health and environmental impacts of specific chemicals • Develop biological methods for predicting health impacts • Develop and standardize bioassay methods for predicting impacts of waste • Develop processes for listing/delisting waste and mixtures using health impacts, environmental impacts, and mobility data • Develop models for screening chemicals for predicting human exposure • Develop data and methodology for estimating health and environmental impacts resulting from exposure to levels of hazardous waste • Develop methods for predicting ground water impacts of pollutants released from landfills • Develop data and methodology for determining likelihood of harm resulting from existing landfill facility • Develop predictive methods for assessing effects of technologies, environments, and waste streams • Develop data and methodology for estimating impacts from ocean disposal • Develop methods for site selection of ocean disposal • Assess hazards for specific chemicals for use by permitting programs • Assess health effects and risks of specific sites in support of permits • Develop guidelines for site evaluation based on pollutant migration for use in permitting • Predict health effects for use in regulatory impact analysis • Evaluate risk assessments for use in RIA for land disposal regulations • Develop data and methodology for estimating health impacts of exposure to various chemicals • Develop improved methods for predicting long-term environmental effects of landfills	• Develop destruction and control efficiency data for incineration, landfill, and land treatment • Develop data on integrity of liners • Identify and evaluate on cost basis technologies for controlling releases of waste from TSDFs • Identify technologies for ocean incineration • Develop data and methodology for land treatment • Prepare guidance manuals for design and performance standards for disposal or treatment • Develop guidance manuals for use by permitting agencies in control capabilities of disposal and treatment technologies • Develop models for estimating lifecycle costs of alternative disposal technologies	• Refining extraction procedures using waste for integration of effects and water quality data • Improve analytical methods for detection of chemicals • Improve dioxin detection methods • Standardize waste characteristic methods for impact analysis • Develop data base for waste mixtures • Provide quality control procedures for automated analytical systems for regulatory application • Develop monitoring and analysis methods for quality assurance of disposal facilities • Issue guidelines for post-closure monitoring of land disposal sites • Complete economic analysis of alternatives to ground water monitoring for land disposal • Develop procedures for determining when Superfund should be used for monitoring and maintenance • Prepare manuals for long-term monitoring of disposal sites • Develop criteria for qualification of sites for Superfund • Develop methodologies for screening waste for enforcement actions • Develop biological methods for demonstrating releases from disposal facilities • Develop methods for estimating costs of long-term monitoring of disposal facilities	• Focus on waste stream mixtures: —determine environmental and health impacts and —treatment and monitoring techniques • Develop new detecting methods, particularly subsurface pollutants • Destruction and recovery of organics • Impacts of reactive and corrosive waste in land treatment facilities • Definition of characteristics which are vulnerable to irreversible damage as result of exposure to chemicals • Focus on persistence and fate of chemicals in environment—biodegradation rates of waste to form basis of monitoring guidelines	• Develop procedures to determine health and environmental effects due to spills of chemicals • Document impacts of chemicals used in treatment of spills, such as neutralizing agents • Develop methods to measure effects of spills on crops and animals • Develop data to correlate responses of aquatic organisms to toxic substances with human health effect data • Develop computer model for predicting toxicity of mixtures • Develop computer model to predict environmental impacts of spills • Develop environmental tests for estimating hazards of spilled materials • Prepare prevention, control, and compliance studies of new techniques for handling spills • Maintain emergency response capability for sampling, analysis, and remote monitoring • Develop manuals for response teams

SOURCE: Office of Technology Assessment.

the agency itself. The apparent intention is for most reports to be distributed in the future through NTIS which, for some users, represents a significant increase in acquisition cost and a considerable reduction in convenience and ease of access to the reports.

Full-Scale Demonstration Facilities.—Under subtitle H, section 8004 of RCRA authorizes the EPA Administrator to enter into contracts or provide financial support for the construction of full-scale demonstration facilities where certain conditions are met (e.g., that the facility will demonstrate a significant improvement in a technology or process, and that it would not receive adequate support from other sources).[140] No use has yet been made of this provision for the construction of demonstration facilities for hazardous waste management technologies.

Federal, State, and Private Compliance Cost for the Current Hazardous Waste Management Program

Introduction

The Resource Conservation and Recovery Act, which establishes a comprehensive hazardous waste management program, reflects the congressional belief that the benefits of the program will exceed the costs of implementation. RCRA does not call for a balancing of costs and benefits in regulatory decisions involving hazardous wastes. Quantitative estimates of the expected benefits, resulting from the increased level of protection of human health and the environment from damages due to the mismanagement of hazardous wastes, are not available. However, some information is available on the costs, and this chapter provides a summary of the estimates that have been made. EPA estimates focus on the potential incremental costs (i.e., those directly attributable to compliance with RCRA regulations) as opposed to those attributable to independent or pre-RCRA efforts. (There are also costs incurred for the CERCLA program; however, these are not generally considered as "regulatory" compliance costs.) Estimates of industrial compliance costs and Federal and State administrative costs are summarized in the following sections. A final section presents total national costs associated with all hazardous waste activities.

Industrial Compliance Costs

The Hazardous Waste Services Industry.—One measure of the impact of complying with government regulations is the amount of money spent by the private sector to manage hazardous wastes. This can be roughly estimated by a two-step analysis. First, the sales are obtained for those firms providing treatment, storage, and disposal services at offsite, commercial facilities. Second, the ratio of offsite to onsite (i.e., generator) management of hazardous waste is estimated. Using this ratio and assuming that noncommercial facilities have approximately the same level of costs per tonne of waste, the onsite or generator management costs are derived. Total costs to waste generators are then estimated by combining commercial and noncommercial waste management costs.

Two studies are available for obtaining the sales of the commercial waste management industry. The summary data from these studies, including projections to 1990, are given in table 63.

The analysis by A. D. Little was based on 1981 revenues from hazardous waste activities for three categories of firms: 1) 9 full service, nationally oriented firms with a subtotal of

Table 63.—Characteristics of the Commercial Offsite Hazardous Waste Management Industry

	A. D. Little[a]		Frost & Sullivan[b]	
	1981	1990	1980	1990
Total hazardous waste generated (millions of metric tons)	43[c]	56	60	85
Proportion of waste managed offsite (percent)	20	80	15	15-25
Average treatment/disposal price (1981 dollars/metric ton)	$100	$200	—	—
Estimated industry revenues (billions of 1981 or 1980 dollars)	$0.9	$9	$0.5	$2.5

SOURCES: [a] Joan B. Berkowitz, "Outlook for the Hazardous Waste Management Services Industry," September 1982, draft from A. D. Little.
[b] Frost & Sullivan, "Hazardous Waste Market—Handling, Storage and Disposal," February 1981.
[c] From EPA, December 1980.

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[140] 42 U.S.C. 6984.

$301 million; 2) 222 regionally or locally oriented firms usually specializing in a limited range of services with a subtotal of $179 million to $277 million; and 3)"unpermitted" firms* with a subtotal of $300 million to $400 million. A. D. Little's projections from 1981 to 1990 are based on an assumed annual growth rate of 3 percent for hazardous waste generation (noting that the EPA estimate for 1981 may be low), which is acknowledged to be conservative. Offsite management is assumed to change from 20 percent at present to 80 percent of the total amount of waste in 1990; it is acknowledged that this projection may be high. The average price is assumed to double from about $100/tonne in 1981 as landfill capacities decline and regulatory actions force the use of more costly options such as incineration and chemical treatment. The increase in total sales from $900 million in 1981 to $9 billion in 1990 corresponds to an average annual growth rate of 29 percent.

The second study by Frost and Sullivan analyzes the 1980 revenues of seven large national-type firms and presents an extrapolation to all of the commercial waste management firms, a projection to 1990 assuming a growth rate of 20—25 percent per year in revenues, an estimate for waste generation in both 1980 and 1990, and a modest increase in the fraction of waste managed offsite.

The results of both studies for current spending for offsite, commercial hazardous waste management are in relatively good agreement. They indicate that the total amount spent in 1980 and 1981 for both onsite and offsite hazardous waste management was probably in the range of $4 billion to $5 billion annually (in current dollars).** These figures, although approximate, are probably low for two reasons. Significant funds are also spent by the private sector on technical consulting and analytical services, but exact figures for these costs are not available. Also, spending on transportation services have not been determined exactly. However, exclusion of these two cost areas may balance the potential for overestimating in the procedure used here. Assuming that onsite management costs are equal to offsite costs probably overestimates total costs, as onsite management is generally understood to be less costly. This results from two factors: 1) onsite efforts generally manage wastes requiring the least costs; and 2) there are more economy-of-scale savings for large onsite activities which often deal with fewer wastes than offsite facilities.

The projections to 1990 with regard to the fraction of the total amount of waste managed offsite are also subject to some uncertainty. However, both studies indicate a similar level of total spending for offsite and onsite hazardous waste management in 1990. The A. D. Little study indicates $11 billion and the Frost and Sullivan indicates $12.5 billion (not adjusting for inflation).

To put these total present and projected levels of industry spending into some perspective, hazardous waste management costs represent about 1 to 2 percent of total annual sales for the chemical and allied products industry, assuming that about 50 percent of all hazardous wastes are generated by this industry, which has generally been found to be the case. Naturally, this percentage will vary significantly among different industries.

EPA Estimates.—This section provides available estimates of the costs to the private sector of complying with the RCRA Subtitle C regulations, based on analyses prepared for EPA in support of the promulgation of these regulations. The analyses cover the expected costs of compliance with the interim status standards, with the interim final design and operation standards for land disposal facilities, and with the financial responsibility requirements for hazardous waste facilities. Cost estimates are not yet available for some of the facility permit standards either because they have not yet been promulgated or because cost analyses have not been completed. Consequently, published data are necessarily incomplete and do not reflect the total compliance costs for the RCRA regulations.

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*It is presumed that these unpermitted firms include a large number of facilities that are generally exempted from RCRA regulation such as recycling operations.

**The A. D. Little study indicates $4.5 billion for 1981, and the Frost-Sullivan study indicates $3 billion for 1980, using their figures for revenues and their fractions of offsite management of 0.2 and 0.15, respectively.

Although OTA attempted to locate alternative (non-EPA) estimates for purposes of comparison and validation, these efforts proved unsuccessful. An examination of three of the best known annual surveys of industrial expenditures on pollution control (conducted by McGraw-Hill, the Bureau of Economic Analysis, and the Bureau of the Census) did not yield useful comparisons because some unknown portion of the reported expenditures are attributable to solid waste activities and not to hazardous waste regulatory compliance costs.

It is important to emphasize that the absence of data comparable to the EPA cost analyses inhibits any direct empirical validation of the EPA results.

The costs of complying with the subtitle C regulations will be incurred at various times during the remaining lifetime of the facilities involved and, in some cases, after closure. To simplify comparisons, EPA has "annualized" its cost estimates by presenting them in the form of "annual revenue requirements," signifying the annual revenues that facilities would have to obtain in equal installments over a 20-year period to offset the costs of compliance. For annualizing each facility is assumed to have a remaining life of 20 years, although costs associated with the financial requirements are taken into account over a 50-year period.

Table 64 provides a summary of EPA's estimates of total annualized compliance costs for implementation of the various sections of RCRA. As mentioned above, these estimates are incomplete since they do not cover all of the anticipated Phase II regulations. Nevertheless, it can be seen from the table that the costs of complying with the performance standards for the owners and operators of treatment, storage, and disposal facilities (under RCRA sec. 3004) are expected to be significantly greater than the costs associated with other RCRA sections. These other sections (providing mostly for general operations such as manifest preparation, waste analysis, recordkeeping, etc.) are a relatively minor portion of the total costs of compliance. EPA analyses indicated that the most significant cost impacts of the ISS regulations for land disposal facilities were for the installation of ground water monitoring systems (an average of $23,000) and for closure and post-closure costs. Only ground water monitoring involves substantial immediate expenditures for existing facilities.

Table 64.—EPA Estimates of Annualized RCRA Compliance Costs by Subtitle C Section
(in millions of 1981 dollars)

Section	Annualized cost
3001-identification and listing	$68.6
3002-generator standards	58.5
3003-transporter standards	0.6
3004-TSDF owners and operators	916.2-1,832.7
3005-permit requirement	1.8
Total	$1,045.8-$1,962.3

SOURCES: Environmental Law Institute, "Costs of Implementing Subtitle C of the Resource Conservation and Recovery Act," OTA Working Paper, October 1982; and A. D. Little, *Economic Impact Analysis of RCRA Interim Status Standards*, 1981.

Compliance Costs for Land Disposal Facilities

The costs of complying with RCRA section 3004 requirements can be subdivided into the costs associated with the interim status standards and those associated with the final (Phase II) standards. Table 65 summarizes EPA's estimates of the total incremental annualized costs of meeting the Phase II requirements for land disposal facilities. The estimates compare Phase II incremental compliance costs with baseline pre-ISS costs for landfills and surface impoundments (e.g., land acquisition, excavation, and infrastructure costs) and ISS costs for all land disposal facilities. The table includes low and high estimates for the Phase II incremental costs, based on differing assumptions about the installation of liners, the occurrence of leaks, and the need for corrective action.

EPA estimated the total annualized incremental costs of complying with the interim status standards for land disposal facilities at $341 million. Implementation of the part 264 permitting standards would, according to EPA estimates, impose additional annual revenue requirements of $150 million to $1,145 million depending on the need for corrective action.

Table 65.—Total Annual Revenue Requirements for Part 264 Regulations (millions of current dollars)

Compliance requirements for existing facilities	Baseline[a] (pre-ISS & ISS)	Incremental Part 264 Low estimate[b]	Incremental Part 264 High estimate[c]
Landfills (design and operating (D&O) requirements)	$301[d]	81	159
Surface impoundments D&O	534[e]	102	401
(Adjustment for landfilled materials)[f]	(190)	(57)	(118)
Waste piles D&O	16[g]	7	12
(Adjustment for landfilled materials)[f]	(10)	(3)	(6)
Land treatment D&O	51[h]	20	20
Total D&O	702	150	468
Corrective action	—	—	677
Total	702	150	1,145

[a] Baseline costs include pre-ISS costs such as land acquisition, excavation, and infrastructure expenses incurred in establishing a land disposal facility and ISS compliance costs imposed under May 1980 regulations including closure and post-closure care, ground water monitoring, and financial responsibility requirements. Approximately 72 percent of the $341 million ISS costs included in the baseline are attributable to closure ($82 million), post-closure ($40 million), ground water monitoring ($42 million), and financial assurance ($82 million) requirements. Baseline costs include estimated pre-ISS costs for landfills and surface impoundments only.

[b] Low estimate assumes installation of single synthetic liners at landfills and replacement of containment system for waste piles to avoid ground water monitoring requirements. No facilities leak, therefore, no corrective action required.

[c] High cost estimate assumes installation of double synthetic liners at landfills, closure of all existing surface impoundments and replacement with new impoundment with double synthetic liner. All facilities immediately begin to leak and require extensive counterpumping corrective action for 150 years.

[d] Includes $181 million in pre-ISS costs for landfills.

[e] Includes $180 million in pre-ISS for surface impoundments.

[f] Some materials, sludges, and residues from surface impoundments and waste piles are eventually sent to land disposal facilities. Adjustment to total is made to avoid double counting of compliance cost of landfilling of materials from these facilities.

[g] Pre-ISS costs not available for waste piles.

[h] Pre-ISS costs not available for land treatment facilities.

SOURCE: 47 F.R. 32,338, July 26, 1982.

EPA analyses of compliance costs of RCRA regulations use a number of key assumptions that can significantly affect the results, including:

1. the use of unit cost data;
2. the annualizing process;
3. the ratio of onsite and offsite disposal;
4. the number of facilities incurring compliance costs;
5. the costs incurred by new facilities;
6. ground water protection and the need for corrective action; and
7. the rate of permitting and the timing of compliance.

1. **The use of unit cost data.**—EPA's analyses are based on unit "engineering" costs. Hazardous waste facilities differ widely depending on their particular characteristics. However, it is common in EPA cost analyses to use model plants that represent the average range of facilities in the relevant universe. Once these models have been specified, compliance costs for each are based on the costs of unit operations. This approach usually leads to an overestimate of actual costs since it fails to allow for technological changes and innovative regulatory responses that tend to lower average costs in practice.

2. **The annualizing process.**—The annualizing process assumes a 7-percent inflation rate in calculating future costs, and then uses a 10-percent discount rate in discounting these costs back to the present; thus, a "real" discount rate of 3 percent is used. No justification for this choice of discount rate has been offered, nor is any analysis presented on the sensitivity of resulting cost estimates to the discount rate selected.

3. **The ratio of onsite to offsite disposal.**—EPA's analyses make an arbitrary allocation between onsite and offsite disposal based on an estimate of the volumes below which it might be considered uneconomical to dispose onsite. For this purpose, an assumption about the cost of offsite disposal is necessary. This ratio does not reflect the influence of other, noneconomic considerations, such as liability, type of waste, or age of the facility, in the onsite/offsite deci-

sion. This assumption could tend to indicate higher total offsite disposal costs and lower total onsite disposal costs.

4. **The number of facilities incurring compliance costs.**—EPA calculated the design and operating compliance costs only for the 5,662 existing land disposal units that submitted part A applications including:

- 573 landfills with 12 million tonnes per year capacity;
- 4,240 surface impoundments with 11,169 acres surface area;
- 608 waste piles with 87 million cubic feet of waste;
- 241 land treatment units with 12,100 acres of operating area.

According to EPA, this will overstate the number of facilities that will actually incur compliance costs as some will close before permitting, and some facilities include several types of units within a single operation and will achieve some economies of scale in full-status standard requirements. EPA calculated corrective action costs only for 2,484 disposal facilities—the number of disposal facilities that submitted part A applications which is less than the total number of existing units because one facility can have several units. This could overestimate the number of disposal facilities, but could underestimate the number of corrective actions. EPA assumed that extensive corrective action would be taken for an entire facility, not separately for each unit in the facility. (See ch. 4 of this report for a more accurate estimate of existing facilities.)

5. **The costs incurred by new facilities.**—EPA did not calculate the incremental costs of complying with part 264 standards for new land disposal facilities because it was difficult to project the number of facilities affected and, moreover, cost estimates were not available for the part 267 temporary standards for new facilities. Exclusion of compliance costs for new facilities will tend to underestimate total costs.

6. **Ground water protection and the need for corrective action.**—EPA could not predict how the owners and operators of TSDFs will react to the liner and ground water monitoring requirements (i.e., whether they will install liners, monitoring systems, etc.). Nor did EPA attempt to predict the incidence of leakage, the need for corrective action, and the costs associated with corrective action. For the purpose of producing estimates, EPA made two extreme sets of assumptions: a low-cost case and a high-cost case. The low- cost case assumes that all landfills use single synthetic liners, all waste piles are replaced to avoid the need for ground water monitoring, no leakage occurs, and no corrective action is needed. The high-cost case assumes that all landfills have double synthetic liners, all waste piles monitor ground water, all surface impoundments are closed and replaced by new units with double liners, and, even with all these precautions, all facilities require immediate corrective action using an expensive counter-pumping strategy for over 150 years. The two cases are so extreme that it is difficult to estimate the costs of a probable intermediate scenario.

7. **The rate of permitting and the timing of compliance.**—EPA's analysis assumed that all facilities are permitted simultaneously and immediately so that compliance costs for all units are occurred at the same time. An earlier study for EPA of the costs of proposed final permitting standards found that the targetting and rate of permitting efforts by EPA (i.e., how quickly must meet permit standards and which industries are permitted first) were among the most important variables affecting annualized compliance costs that are under EPA's control.* Total annualized compliance costs are probably overstated as a result of this assumption. Existing facilities will continue to operate under interim status standards until permitting. EPA has estimated that initial permitting of over 2,100 existing land disposal facilities will not be completed until fiscal year 1988.

EPA's analysis concluded that the compliance costs for the land disposal regulations might lead to the closure of small onsite land-

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*Development Planning Associates, Inc., Pope Reid Associates, Inc., Putnam, Hayes and Bartlett, Inc., and Temple, Barker, and Sloane, Inc., *Final Impact Analysis of Proposed RCRA-FSS Regulations, 1980-1990*, November 1980, pp. 4-5.

fills an the closure and replacement of small onsite surface impoundments. EPA estimates that there are about 225 small landfills (500 tonnes/yr or less) representing about 44 percent of all landfills. The 2,760 small surface impoundments (one acre or less) represent about 65 percent of all surface impoundments. Compliance costs for these facilities are expected to be substantially higher on a per unit basis than for the larger commercial facilities.

EPA estimated that part 264 design and operating standards would add from $10 to $22 per tonne to disposal costs at a midsize landfill (15,000 tonnes per year) depending on the type of liner installed. Corrective action costs would add an additional $2 to $21 per tonne in annual revenue requirements depending on the type and extent of remedial measures required. In contrast, a small (500 tonnes per year) landfill would require annual revenues of $62 to $104 per tonne to offset incremental compliance costs for design and operating requirements and additional annual revenues of $34 to $396 per tonne for potential corrective action costs.

EPA estimated that commercial landfill disposal charges in 1981 ranged from $55 to $240 per tonne depending on the type of wastes and excluding transportation costs. Compliance with interim status standards and Phase II permitting standards are not expected to increase these charges significantly for the larger facilities even if corrective action is needed.

EPA did not analyze the impact of the land disposal regulations on the use of alternative treatment technologies. However, a comparison of available information about charges at alternative treatment facilities and commercial landfills in California suggests that the economic impacts of complying with EPA's land disposal regulations will not result in any significant economic incentive to use alternative waste management technologies.* According to a California report, the charges for landfilling hazardous wastes range from $20-$200 per ton depending on the type of wastes, with the highest costs for containerized highly hazardous wastes. The range of average costs for alternative treatment options were: surface impoundments, $20-$30/ton; incineration, $250-$500/ton; chemical stabilization, $100-$120/ton; and other chemical and physical treatment processes, $30-$175/ton. Even assuming an initial 20- to 30-percent increase in land disposal costs, landfilling will remain the least expensive alternative for most wastes. For highly-hazardous wastes, landfilling will probably still be less costly than incineration or other suitable treatment alternatives under EPA's land disposal regulations.

Financial Responsibility Compliance Costs

EPA has promulgated regulations requiring the owners and operators of hazardous waste TSDFs to demonstrate adequate financial capability: 1) to close a site and conduct necessary routine post-closure activities; and 2) to compensate third parties for damages from releases of waste constituents during the active life of the facility.

These requirements, however, have undergone several administrative changes. The interim status standards initially required that the facilities should create a trust fund based on their estimated costs of closure and post-closure activities. Later revisions allowed more flexibility in demonstrating financial responsibility, such as obtaining a surety bond, letter of credit, closure insurance, or meeting a financial test. For third-party liability, the current regulations require self-insurance backed by a financial test or outside insurance coverage of $3 million per nonsudden accidental occurrence with an annual aggregate of at least $6 million, and $1 million per sudden accidental occurrence with an annual aggregate of at least $2 million. EPA's estimate of the total compliance cost of these regulations is shown in table 66 for four types of facilities. Since the cost for any given mechanism depends on the absolute closure cost or third-party damage and the risk perceived by the institutions backing the facility, it is understandable that surface impound-

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*Toxic Waste Assessment Group, *Alternatives to the Land Disposal of Hazardous Wastes: An Assessment for California* (Governor's Office of Appropriate Technology: 1981).

Table 66.—Present Value of the Private Costs of RCRA Financial Responsibility Regulations by Type of Facility (in millions of dollars)

Type of facility	Financial assurance		Liability	
	Closure	Post-closure	insurance	Total
Storage	$89.6	0	$47.9	$137.5
Surface impoundment	69.6	$514.6	608.4	1,192.6
Landfill	34.6	268.4	193.7	496.7
Incinerator	15.3	0	6.9	22.3
Total	$209.2	$783.0	$856.8	$1,849.1

SOURCES: Environmental Law Institute, "Costs of Implementing Subtitle C of the Resource Conservation and Recovery Act," OTA Working Paper, October 1982; and Putnam, Hayes & Bartlett, *Regulatory Impact Analysis of the Financial Assurance and Liability Insurance Regulations*, 1981, p.40.

ments ranked highest in terms of costs and incinerators lowest. The total cost calculations were based on an assumed distribution of facilities using each of the alternative mechanisms shown in the table.

The distribution was considered by EPA as the most reasonable. EPA estimated that if the percentage of facilities that can pass the financial test increases to 50 percent there will be a decrease of 40 percent in compliance cost. On the other hand, if the same percentage drops to 10 percent there will be a 70-percent increase in compliance cost.

Cost by the types of financial mechanism for landfills are presented in table 67. Trust funds, originally required by ISS rules, are the most expensive form of financial assurance. EPA assumed that the facility pays 5 percent of the total closure and post-closure costs each year into a fund during the interim status, and once the permit is issued the remaining portion is paid over the life of the permit for a maximum period of 10 years.

Table 67.—Annual Cost of Financial Assurance Activities per Facility for Owners and Operators of Treatment, Storage, and Disposal Facilities (1981 dollars)

Financial mechanism	Percent of facilities	Amount
Trust funds	17%	$ 1,834 (closure) $4,844 (post-closure)
Surety bonds	Negligible	0.85% of face value
Letter of credit	17%	Negligible
Financial test	33%	$595 (closure)
Insurance policy (closure)	33%	$1,206 (post-closure)
Insurance policy (liability)	--	$480-$11,040 (sudden) $21,120 (nonsudden)

SOURCES: Environmental Law Institute "Costs of Implementing Subtitle C of the Resource Conservation and Recovery Act," OTA Working Paper, October 1982; and Putnum, Hayes & Bartlett, *Regulatory Impact Analysis of the Financial Assurance and Liability Insurance Regulations*, 1981.

The surety bond is essentially a contract between the facility owner or operator and a surety company which guarantees to pay for the costs of closure and post-closure activities if the owner or operator does not. The after-tax cost of the surety bonds was calculated to be about 1 percent of the face value of the bond. A letter of credit is similar to the surety bond and commits the bank holding the letter of credit to pay for the cost of closure and post-closure activities if the facility does not. The cost of the letter of credit consists of the fee to the bank and the cost of providing some form of collateral or about 0.85 percent of the value of the letter of credit. The facility may also fulfill the regulatory requirement by buying insurance coverage which will pay for the closure and post-closure costs if the facility cannot. This is also true of the liability insurance coverage except the premiums are much higher. Finally, the cost of a financial test is minimal—the one-time cost of preparing a special auditor's report.

Because the financial requirement is more of a performance standard than a design and operation standard, the unit cost per site is probably more important than the total cost, although no one knows for sure the number of facilities using each of the mechanisms. Although the financial test mechanism appears to be the lowest cost option, the actual cost of the regulation will depend on the stringency of the test.

Federal Administrative Costs

To implement RCRA, the Federal Government must support a wide range of activities from regulation development and the basic research underlying these regulations to enforcement of the final rules. The bulk of these responsibilities and costs falls on the EPA. This section outlines the major cost components in administering EPA's hazardous waste management program.*

Data Sources and Limitations.—The Federal expenditure figures presented here come from EPA's 1983 and 1984 budget justification presented to the House Committee on Appropriations and from final fiscal year 1983 appropriations for EPA passed in September 1982. Although the 1981 and 1982 figures represent actual expenditures, the 1983 and 1984 figures, as proposed, may not accurately reflect actual outlays in those years.

Some costs incurred by other program offices in EPA may not be included in the estimates presented here. For example, the Office of Planning and Resource Management conducts some RCRA-related research, and the Water Office conducts RCRA impact studies in conjunction with the development of effluent guideline background documents. Although this kind of work may be funded in part through the Office of Solid Waste and thus be included in the EPA hazardous waste totals, any other program office expenditure (excluding enforcement and research and development) probably will be missed. Not all hazardous waste program costs can be formally thought of as RCRA-induced. Presumably EPA would be undertaking some hazardous waste research (e.g., even in the absence of RCRA), but no attempt is made here to estimate what percentage of EPA's activities would fall into this category.

These limitations and characterizations of the Federal administrative cost data suggest that the figures used here are lower bound estimates of actual RCRA implementation costs. However, one would not expect the difference from the true costs to be great.

EPA Administrative Costs.—Total administrative costs of EPA's hazardous waste program for the years 1975-83 are presented in table 68 and figure 23. These costs are also broken down into three general program activities:

- **Abatement, control, and compliance:** includes regulatory activities, development of regulations, guidelines and policies, financial assistance to State programs, and waste management strategies (coordinating regional office activities, permitting State programs, and cooperative appeal negotiations).
- **Enforcement:** originally permit issuance, compliance inspections, and enforcement support (in fiscal year 1983 most responsibilities transferred to other divisions.)
- **Research and development:** EPA technical support research on waste listing and identification, environmental and health effects, etc.

In real terms, expenditures during the years 1975-78 show a generally upward trend with relatively small percentage changes between

Table 68.—Hazardous Waste Programs, 1975-81[a] (dollars in thousands)

Year	Total	Abatement, control, and compliance	Enforcement	Research and development
1975	$20,184	$12,180	—	$7,374
1976	15,405	12,594	—	2,811
1977	18,688	14,458	$3	4,229
1978	35,766	27,743	618	7,405
1979	62,521	52,554	1,515	8,452
1980	109,775	90,624	6,038	13,113
1981	141,428	101,705	11,391	28,301

[a] Includes expenditures on solid waste and resource recovery programs that have been largely discontinued in 1982-83. Solid waste and resource recovery expenditures were approximately $13 million in fiscal year 1981.

SOURCE: Congressional Budget Office, "Preliminary Analysis of the Proposed 1983 EPA Budget," draft staff memorandum, Mar. 9, 1982.

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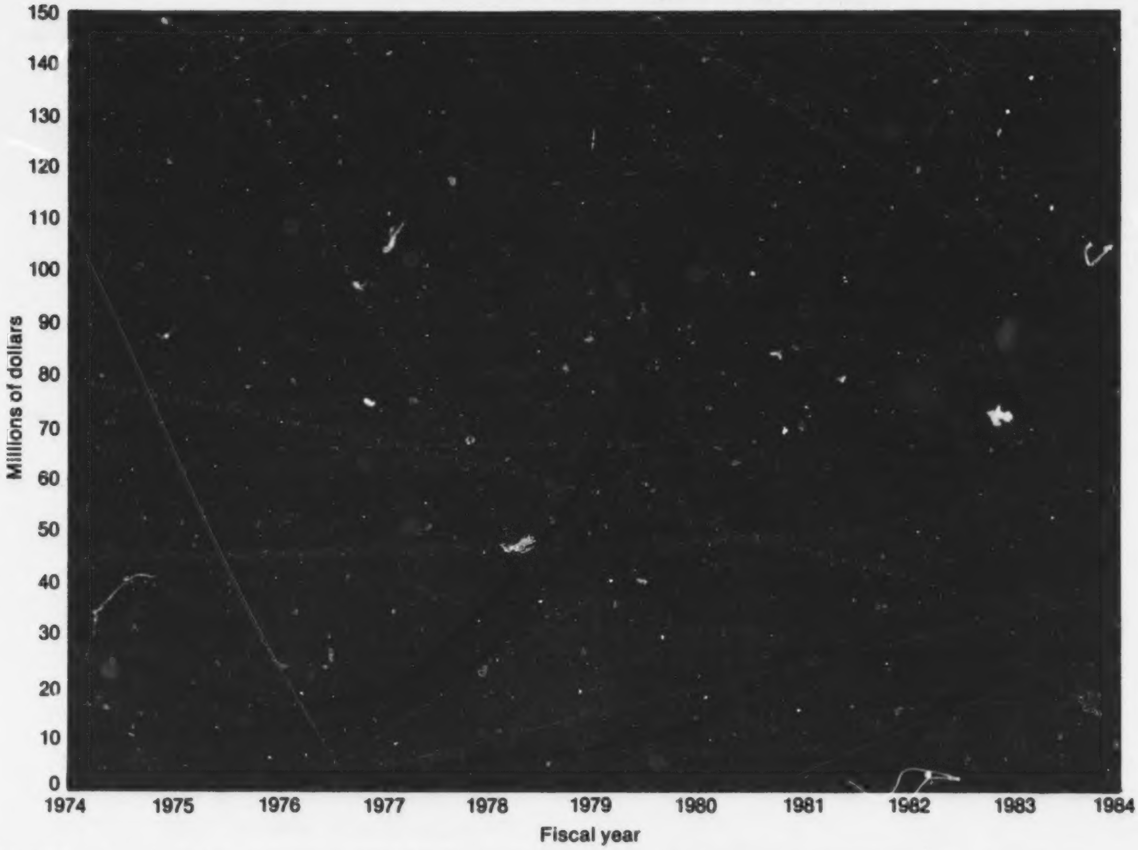
*There are other costs incurred by other Federal agencies as a result of Subtitle C of RCRA, such as the costs of compliance with the RCRA regulations at Federal facilities; however, available appropriations budget data did not provide specific cost figures for hazardous waste control expenditures by agency, but rather total environmental control expenditures. Other agencies may incur small costs in implementing specific subtitle C requirements, but no estimates of possible administrative costs to other agencies have been identified.

Figure 23.—EPA Hazardous Waste Program Budget 1975-83[a]



[a] 1975-80 Budget includes solid waste, resource recovery, and abandonment sites, In 1981-83, solid waste and resource recovery expenditures were discontinued; abandoned site efforts were transferred to Superfund program.

years in all activities except research and development, which dropped by approximately 49 percent. As expected with passage of RCRA in 1976, expenditures from 1978 through 1981 showed the largest percentage increases in real and nominal terms, with total expenditures increasing by over 300 percent; abatement, control, and compliance by 290 percent; enforcement by over 1,000 percent; and research and development by over 300 percent. The generally downward trend in hazardous waste program expenditures in 1980-81 is primarily due to transfer of abandoned site activities to the Superfund program.

The across-the-board decreases in 1982 and 1983 expenditures reflect the budget cuts sought by the Reagan Administration. The largest cuts are in the enforcement budget, which by 1983 will have declined by 86 percent from 1981 levels. However, part of this decrease is due to EPA reorganization and the consolidation of permitting and enforcement activities and represents a transfer of expenditures to an all-EPA interdisciplinary office of legal and enforcement counsel.

The three general program activities are broken down into specific expenditure categories for the years 1981-84 in table 69 (unlike the previous table, this table is for authorized trends rather than obligations). The figures demonstrate the relative activity emphasis within the program and the probable changes

Table 69.—EPA Hazardous Waste Program Federal Administrative Costs for Fiscal Years 1981-84

Program component	1981 actual	1982 actual	1983 estimate	1984 estimate
Abatement, control, and compliance	***$79,129.9***	***$73,472.8***	***$81,213.7***	***$79,213.9***
Regulations, guidelines, and policies	20,221.4	21,474.1	24,115.7	20,592.3
Financial assistance (grants to States)	39,672.4[a]	42,344.8[a]	44,068.0	42,500.0
Waste management strategies (regional offices and permits	14,385.5	9,556.4	13,030.6	16,121.6
Technical assistance	4,850.6	97.5	0.0	0.0
Enforcement	***6,328.4***	***6,707.0***	***2,385.7***	***3,509.5***
RCRA permit issuance[b]	3,259.7	3,191.5	(b)	(b)
RCRA enforcement[c]	3,068.7	3,515.5	2,385.7	3,509.5
Research and development	***28,301.3***	***29,246.9***	***32,951.5***	***27,389.3***
Scientific assessment	548.3	715.2	1,543.7	1,511.8
Technical information	157.1	178.9	(d)	(d)
Monitoring systems and quality assurance	9,398.1	6,734.3	7,283.0	7,016.4
Health effects	464.9	1,332.4	1,068.4	968.1
Environmental engineering techniques	17,160.3	16,930.5	18,078.6	13,251.8
Environmental processes and effects	572.6	3,355.6	4,977.8	4,641.2
Total hazardous waste program	$113,759.6	$110.578.4	$116,551.5	$110,122.7

[a] Includes solid waste and resource recovery grants, discontinued in 1982-83.
[b] Transferred to Waste Management Strategies in fiscal year 1983.
[c] Part of the program effort transferred to Office of Legal and Enforcement Counsel in fiscal year 1983. Remainder includes technical enforcement efforts in regional offices.
[d] Consolidated into Intermedia programs in 1983.

SOURCES: 1981 actual: *Hearings on HUD Independent Agencies Appropriations for 1983 Before Subcommittee of the House Committee on Appropriations,* 97th Cong., 2d sess., part 3. 1982-84: U.S. Environmental Protection Agency, *Justification of Appropriation Estimates for Committee on Appropriations FY 1984,* January 1983.

taking place over this period. Abatement, control, and compliance activities (regulation writing and analysis, grants to States, regional office funds to assist States, and public information programs) make up the largest portion of overall program expenditures, with the State grant program taking up the largest percentage share (34 percent of the total budget request in 1983). The technical assistance category which involves State, local, and public information programs was phased out in 1982.

Activities for waste management strategies implementation show a marked decrease from 1981-82. This category includes the costs of operating the regional EPA office responsibilities for hazardous waste. The decline in costs shown for regional activities is not reflected in 1983 totals because hazardous waste permit issuance costs, a separate activity under enforcement in 1981 and 1982, are included in the regional category as of 1983. Presumably, part of the reason for the decrease is due to an anticipated greater level of State-controlled programs.

The enforcement activity costs show the largest overall percentage decrease (80 percent) of any program area. This is somewhat misleading, however, since the hazardous waste permit issuance category was included, as of 1983, in the waste management strategies category, and enforcement responsibilities were in part shifted to the Office of Legal and Enforcement Counsel in another EPA program category. Again, the justification for this decrease is not clear; it may be a result of more streamlined administration, greater State responsibility, or it may reflect a reduction in the priority attached to enforcement.

EPA research and development expenditures have remained relatively stable from 1981 to 1983. But this total hides major increases in certain small budget activities, for example, the research on environmental impacts of hazardous wastes (environmental protection and effects). Extramural (external grant and contract) resources declined for activities directed toward waste-listing priorities (scientific assessment); providing guidelines for identifying wastes (monitoring and quality assurance); and the generation of technical data bases to support regulation development. Overall, however, expenditures increased substantially for scientific assessment, health effects, and environmental protection and effects. Expenditures decreased significantly in monitoring quality assurance and environmental engineering technology, both large-expenditure activities.

State Administrative Costs

Under the RCRA strategy for a national hazardous waste management system, States may assume responsibility for regulating hazardous waste activities by developing and implementing regulatory programs that meet certain requirements. To assist the design of a workable system, and to make that system operational, EPA makes funds available to States. Although these grants can cover a large portion of State expenditures for hazardous waste regulation, each State must contribute a minimum percentage of its own funds to the program. This section presents estimates of State expenditures for developing and operating State hazardous waste programs under RCRA for selected States.

Data Sources and Limitations.—The data presented in tables 70 and 71 represent, in most part, actual and budgeted State expenditures for hazardous waste management programs. Obtaining State figures is difficult. Although OTA attempted to obtain this data from EPA, only Regions V, VII, VIII, and IX provided data. Further, only Region V could provide budget figures by activity. Some additional information came from a survey conducted by the Association of State and Territorial Solid Waste Management Officials.

Table 70.—Federal Financial Assistance Grants for Hazardous Waste Management by State, 1981-83 (thousands of dollars)

Region/State	1981	1982	1983 estimate[a]
Region I:			
Connecticut	$358	$498	$420
Maine	150	209	176
Massachusetts	639	888	749
New Hampshire	150	209	176
Rhode Island	196	272	230
Vermont	150	209	176
Region II:			
New Jersey	893	1,241	1,046
New York	1,682	2,338	1,971
Puerto Rico	170	236	200
Virgin Islands	150	209	176
Region III:			
Delaware	150	209	176
Maryland	410	570	480
Pennsylvania	1,637	2,280	1,917
Virginia	319	532	449
West Virginia	554	770	650
District of Columbia	150	209	176
Region IV:			
Alabama	585	812	684
Florida	780	1,084	914
Georgia	511	710	599
Kentucky	520	723	609
Mississippi	205	285	240
North Carolina	589	819	690
South Carolina	440	612	516
Tennessee	771	1,073	903
Region V:			
Illinois	1,403	1,950	1,644
Indiana	924	1,284	1,082
Michigan	1,229	1,708	1,439
Minnesota	360	500	422
Ohio	1,637	2,275	1,917
Wisconsin	570	791	668
Region VI:			
Arkansas	202	282	237
Louisiana	984	1,368	1,244
New Mexico	150	209	176
Oklahoma	279	388	327
Texas	2,993	4,160	3,506
Region VII:			
Iowa	280	389	329
Kansas	265	370	311
Missouri	468	651	548
Nebraska	150	209	176
Region VIII:			
Colorado	305	423	357
Montana	173	239	201
North Dakota	150	209	176
South Dakota	150	209	176
Utah	192	267	225
Wyoming	150	209	176
Region IX			
Arizona	380	528	446
California	2,376	3,301	2,783
Hawaii	150	209	176
Nevada	150	209	176
American Samoa	150	209	176
Trust Territories	150	209	176
Guam	150	209	176
Region X			
Alaska	259	359	303
Idaho	166	231	195
Oregon	396	550	464
Washington	439	610	513
Total	$29,137	$41,700	$35,226

NOTE: Columns may not add to totals because of independent rounding.

[a] 1983 grants reflect EPA fiscal year 1983 budget request. Congressional appropriations increased grants to State hazardous waste programs to $44 million in fiscal year 1983 to maintain programs at approximate 1982 levels.

SOURCES: Environmental Law Institute, "Costs of Implementing Subtitle C of the Resource Conservation and Recovery Act," OTA Working Paper, October 1982; and U.S. Environmental Protection Agency, State Grants Office, July 1982.

Table 71.—Fiscal Year 1982 Federal Support of State Hazardous Waste Programs

State	Percent of total program costs	State	Percent of total program costs
Alabama	75	Montana	86
Alaska	40	Nebraska	75
Arizona	77	Nevada	68
Arkansas	75	New Hampshire	39
California	43	New Jersey	24
Colorado	58	New Mexico	75
Connecticut	100	New York	58
Delaware	75	North Carolina	74
Florida	89	North Dakota	75
Georgia	75	Ohio	75
Hawaii	85	Oklahoma	66
Idaho	82	Oregon	79
Illinois	79	Pennsylvania	58
Indiana	75	Rhode Island	100
Iowa	62	South Carolina	60
Kansas	73	South Dakota	83
Kentucky	83	Tennessee	58
Louisiana	59	Texas	75
Maine	100	Utah	71
Maryland	65	Vermont	100
Massachusetts	48	Virginia	73
Michigan	69	Washington	73
Minnesota	41	West Virginia	75
Mississippi	59	Wisconsin	75
Missouri	64	Wyoming	n/a

SOURCE: Thomas W. Curtis and Peter Creedon, *The State of States: Management of Environmental Programs in the 1980's*, Committee on Energy and Environment, National Governors Association, June 1982.

As an accurate reflection of State administrative costs, the data presented here have several notable limitations. First, with the exception of the 1981 data (in some cases), the dollar figures are actual and are for proposed activities rather than actual expenditures. To the extent that, for example, budgets are revised, funds not appropriated, or fiscal year money shifted forward, these figures can differ from actual expenditures. Second, most of the State cost figures are based on financial assistance grant requests to EPA. Since the grant proposals generally include only the minimum State contribution (i.e., that which the State needs to spend to comply with the terms of the grant), the data may be only lower bounds of actual expenditures if States later choose to obligate greater amounts to their programs.

Federal Financial Assistance Grants.—Actual and budgeted Federal grants to all 50 States are presented in table 70 for the years 1981-83. Total financial assistance program funds in any given year are allocated to the States based on a formula that considers: relative population (40 percent); relative amounts of hazardous waste generated (40 percent); relative number of generators (15 percent); and relative land area (5 percent). In addition, the regional administrators have some discretion to vary the actual amounts. (EPA has indicated that this allocation process will be changed.) The States use these figures in formulating their grant requests to EPA. Although the components of the grant requests vary among States, EPA has established working guidelines that call for two-four-person-work years per State for organization and management of interim and final authorization status, and approximate percentages for program activities: program management (15 percent); permitting (50 percent); and enforcement (35 percent). It is not clear how stringently these guidelines are followed in practice.

In theory, the Federal grants provide 75 percent of total State expenditures on hazardous waste program development and implementation. State funds may be drawn from general revenues or in some States from fees on generator, transporter or disposer activities.* In reality, State contributions vary depending on whether the State program is more stringent than that required by EPA and whether the State government is able or desires to appropriate additional funds. Table 72 shows the percentage of Federal support of State hazardous waste programs in 1982.

State Administrative Costs.—Table 71 provides budget expenditures for 22 States for the years for which data are available from the relevant sources. These figures represent State budget expenditures for hazardous waste regulatory programs. For example, the State's share of total expenditures ranged from 0.03 percent in Illinois in 1980 to 70 percent in Minnesota in

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*For a review of State fee mechanisms, see: U.S. Environmental Protection Agency, *A Study of State Fee Systems for Hazardous Waste Management Programs*, Office of Solid Waste and Emergency Response, SW-956, July 1982. (Contrary to the generally optimistic treatment of fees and taxes as State funding mechanisms for hazardous waste activities in the EPA study, other studies indicate that limitations on the use of these mechanisms under State law present substantial impediments. Additionally, the amounts received from fees and taxes are only a small portion of the total administrative cost of State programs.)

Table 72.—State Expenditures on Hazardous Waste Program Activities for Selected States
(current dollars)

State	1980	1981	1982	# of ISS facilities[a]
Arizona	$32,000	$137,300	$233,100	109
California	683,000	2,947,000	4,385,000	781
Colorado		254,840		97
Hawaii		6,900	15,000	29
Illinois	27,585	864,171	679,702	536
Indiana	99,523	326,044	428,120	312
Iowa		75,725	237,739	110
Kansas		114,967	123,034	81
Michigan		431,963	569,648	353
Minnesota	137,040	228,223	457,724	121
Mississippi		73,712	135,957	147
Missouri		220,586	216,833	140
Montana		39,833		27
Nebraska		68,164	69,633	47
Nevada	18,000	18,000	108,000	17
North Dakota		68,309		12
Oklahoma		92,950	580,480	123
Pennsylvania	1,968,000	3,369,600	2,000,000[b]	570
South Dakota		42,332		11
Texas		474,391	739,133	806
Utah		117,879		31
Wisconsin	375,051	464,083	236,822	198

[a] Number of facilities reporting under section 3010.
[b] Projected budget.

SOURCES: Environmental Law Institute, "Costs of Implementing Subtitle C of the Resource Conservation and Recovery Act," OTA Working Paper, October 1982; and EPA Regional Budget Office; Association of State and Territorial Solid Waste Management Officials, *State Measurement Needs Study* (Sept. 30, 1981). It should be noted that the data for Pennsylvania, Oklahoma, Mississippi, and Texas appear to have been drawn from actual State budgets, while the other State data reflect the cooperative arrangement grant requests. These latter figures may underestimate actual State expenditures.

1983. In Wyoming, EPA is operating the entire State program. Most of the data is from Federal grant requests, which may or may not provide an accurate indication of actual expenditures.

Current Total National Costs for Hazardous Waste Control

Considering all spending on hazardous waste activities, including those in the public and private sectors and for both RCRA- and CERCLA-related efforts, OTA's estimate of total national expenditures for 1982 is $4 billion to $5 billion. Current combined Federal and State spending is probably in the range of $200 million to $300 million. The previously derived figure of $4 billion to $5 billion (in current dollars) in private sector spending for 1980-81 must be modified by two factors: 1) industrial activity and waste generation in 1982 is substantially lower than in 1980; and 2) private sector spending related to CERCLA activities is substantially greater in 1982 than previously, with a probable current level of $300 million to $400 million. Finally, although the current amount of waste generated is less than in 1980-81, the unit costs of waste management are higher. Thus, while waste generation may have been reduced by 20-30 percent, costs probably have increased by 10-30 percent. Considering the lack of accurate detailed figures, the estimate of $4 billion to $5 billion for total, national spending appears reasonable.

Part II: State Responses to Hazardous Waste Problems

Introduction

This section describes approaches to regulation of hazardous waste under 1) authorized State programs under the Resource Conservation and Recovery Act (RCRA), 2) State regulatory programs under State laws, and 3) alternative State programs.

The section also discusses various alternatives to "command and control" regulation of hazardous waste through such indirect measures as increased civil liability for damages through legal action, additional insurance and financial responsibility requirements, State trust funds, fees and taxes on hazardous waste activities, and other economic mechanisms.

State Programs Under RCRA

Under RCRA section 3006, a State may exercise primary responsibility for regulating hazardous waste instead of the Federal program administered by the Environmental Protection Agency (EPA) if the State program meets certain minimum Federal standards. While the final Federal program is being developed and State program applications are being reviewed, existing State programs that are substantially equivalent to the Federal program can continue in effect under interim authorization. The legislative history of RCRA indicates that Congress anticipated that the States eventually would assume primary responsibility for hazardous waste management. Two incentives are offered for State participation: first, the opportunity to administer a State program in lieu of a Federal program; and second, Federal financial and technical assistance for development and operation of State program activities and support of Federal programs. Federal RCRA grants can pay for up to 75 percent of State programs with the States contributing the remaining 25 percent of the costs. Current economic conditions and budgetary constraints may result in substantially reduced financial and technical assistance. These reductions could induce some States to decline to apply for authorization and to allow the Federal Government to finance and operate a Federal program within that State. However, a recent Association of State and Territorial Solid Waste Management Officials (ASTSWMO) survey indicated that only a few such instances might be expected if funding is maintained.[141] **The current EPA administrator, Anne M. Burford, has announced an intention to move toward zero funding of State environmental programs. States would thus receive no Federal funds for operating programs that EPA would have to administer and pay for if the State did not.**

As of February 1983, 34 States* and 1 territory had received Phase I interim authorization and 16 States were operating under cooperative arrangements or partial authorizations. Nine States had received Phase II authorization for component A, and many more States were moving to gain Phase II authorization to allow permitting. Still other States, such as Michigan, have announced their intention to apply instead for final authorization. At least one State (Wyoming) has decided not to apply for authorization at this time. With the promulgation of the land disposal regulations in July 1982, EPA announced that States could apply for final program authorization. The current status of State programs is summarized in table 73.

In implementing the State programs for RCRA authorization, at least 15 States have tied their programs to the stringency of the Federal program.[142] State programs can be classified in whole or in part according to these three types:

- State programs that are the same or **"mirror image"** of Federal program requirements;
- State programs that are "no less stringent than" or "at least as stringent as" the Federal program so that the Federal program provides the **"floor"** for State requirements.
- State programs that are "no more stringent than" the Federal program in which the Federal program imposes a **"ceiling"** on State requirements.

Depending on how the State's legislative mandate is written, these restrictions on State programs can have different effects on a State's ability to deal with hazardous waste management in response to Federal action or inaction.

Under a "mirror-image" approach, as a result of statute or policy decision, a State regulatory program adopts the language of Federal regulations in whole or by reference. The State statute may provide, for example, that the State program will be "consistent and equivalent with" or "the same as" or automatically incorporate the Federal regulations.[143] States with a "mirror" approach depend on the adequacy of the Federal program.

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[141] Association of State and Territorial Solid Waste Management Officials (ASTSWMO).

*For RCRA purposes "States" includes U.S. territories and the District of Columbia.

[142] The 15 States are: Colorado, Florida, Illinois, Iowa, Maine, Massachusetts, Montana, New Mexico, New York, North Carolina, North Dakota, Oklahoma, Virginia, and West Virginia.

[143] Illinois hazardous waste legislation authorized the State agency to adopt the EPA regulations as the State program so that the State could quickly receive interim status authorization. Promulgation of standards under Illinois procedures would take a year or more to accommodate public review and comments. In adopting the Federal program by reference, the State did not anticipate that Federal minimum program standards later would be suspended.

Table 73.—State RCRA Program Authorization

State	Current status	Status of applications if known
Alabama	Phase I Interim Authorization received 2/25/81	Phase II to be submitted 1/83
Alaska	Cooperative arrangement	Unsubmitted—scheduled to be submitted 9/83
Arizona	Phase I—8/18/82	Phase II—Expected 1984-85
Arkansas	Phase I Interim Authorization received 11/19/82 Phase II received 4/19/82	
California	Phase I Interim Authorization received 6/4/81 Phase II received 1/11/83[a]	
Colorado	Cooperative arrangement	Unsubmitted—planned 7/83
Connecticut	Phase I 4/21/82	Pending Request to submit 10/30/82
Delaware	Phase I Interim Authorization received 2/25/81	Phase II—unknown
District of Columbia	Cooperative arrangement	Pending—to be submitted by 10/82
Florida	Phase I 5/10/82	Phase II submitted 8/13/82
Georgia	Phase I Interim Authorization received 2/3/81 Phase II received 5/21/82	
Hawaii	Cooperative arrangement	Unsubmitted
Idaho	Cooperative arrangement	Unsubmitted
Illinois	Phase I received 5/17/82	Will ask for full final authorization late 1983 or early 1984 and skip Phase II
Indiana	Phase I received 8/18/82	Unsubmitted Phase II—to be submitted 8/82
Iowa	Phase I Interim Authorization received 1/30/81	Phase II submitted 3/10/82
Kansas	Phase I received 9/17/81	
Kentucky	Phase I Interim Authorization received 4/1/81 Phase II received 1/28/83	
Louisiana	Phase I Interim Authorization received 12/19/80	Phase II submitted 10/82
Maine	Phase I Interim Authorization received 3/18/81	Phase II to be submitted 1/83-2/83
Maryland	Phase I Interim Authorization received 7/8/81	Phase II anticipated date A - 2/15/83 B - 5/15/83 C - 9/15/83
Massachusetts	Phase I Interim Authorization received 2/25/81	Phase II to be submitted Fall 1982
Michigan	Cooperative arrangement	Pursuing Phase I—expect submittal 10/82
Minnesota	Cooperative arrangement since 6/79	Unsubmitted Phase I to be submitted 7/83 Phase II to be submitted 7/83
Mississippi	Phase I Interim Authorization received 1/7/81 Phase II received 8/31/82	
Missouri	Cooperative arrangement	Phase I & II submitted 9/82
Montana	Phase I Interim Authorization received 2/26/81[b]	Planned Phase II submittal 3/83
Nebraska	Phase I received 5/14/82	Phase II undecided as to all or part 9/82
Nevada	Cooperative arrangement	Unsubmitted
New Hampshire	Phase I received 11/3/81	Phase II submitted 10/82
New Jersey	Phase I received 2/2/83	
New Mexico	Cooperative arrangement	Unsubmitted Phase I, II A, B to be submitted 1/83
New York	Cooperative arrangement	Pending—Phase I submitted 1/12/82, Phase II not known
North Carolina	Phase I Interim Authorization received 12/18/80 Phase II received 2/26/82	
North Dakota	Phase I Interim Authorization received 12/12/80	Partial Phase I authorization only, MOU[c] for generators, treatment, transportation Phase II—unknown
Ohio	Cooperative arrangement	Pending Anticipate 11/82 Phase I Anticipate mid 1984 Phase II
Oklahoma	Phase I Interim Authorization received 1/14/81 Phase II received 12/13/82	
Oregon	Phase I Interim Authorization received 7/16/81	Phase II to be submitted 11/82
Pennsylvania	Phase I Interim Authorization received 5/26/81	Phase II to be submitted 12/82
Rhode Island	Phase I Interim Authorization received 5/29/81	Phase II, Part A, to be submitted
South Carolina	Phase I Interim Authorization received 2/25/81 Phase II received 11/3/82	

Table 73.—State RCRA Program Authorization—Continued

State	Current status	Status of applications if known
South Dakota	Cooperative arrangement	Unsubmitted—will submit Phase I & II 1/84
Tennessee	Phase I Interim Authorization received 7/16/81	Phase II submitted
Texas	Phase I Interim Authorization received 12/24/80 Phase II received 3/23/83	Note 2 different programs TOWR[d]—2/82 received Phase I TOWR—3/83 received Phase II TDH—Phase I 12/80 TDH—Phase II 3/28
Utah	Phase I Interim Authorization received 12/12/80	Phase II submitted
Vermont	Phase I Interim Authorization received 1/15/81	Phase II submitted by 12/82
Virginia	Phase I received 11/3/81	Phase II submitted end 1982
Washington	Cooperative arrangement	Unsubmitted—submitted Phase I, II A & B expect approval 1/83
West Virginia	Cooperative arrangement	Unsubmitted
Wisconsin	Phase I received 1/15/82	Phase II will go to final authorization 6/84
Wyoming	Cooperative arrangement	Unsubmitted
Puerto Rico	Phase I received	

[a] California is not authorized to control storage or treatment in surface impoundments. Part A only.

[b] Montana received partial authorization for Phase I on 2/26/81 and complete Phase I authorization on 2/17/82.

[c] Memorandum of Understanding.

[d] TOWR—Texas Office of Water Resources; TDH—Texas Department of Health.

SOURCE: ASTSWMO Survey for OTA; Government Institutes, Inc., *Hazardous Wastes Facility Handbook*, 3d ed. (1982), prepared by Tom Watson, Ridgway M. Hall, Jr., Jeffrey J. Davidson, and David R. Case; and OTA Staff research.

According to testimony presented before a congressional committee, West Virginia's State legislation requires that the State rules be "consistent and equivalent with" the Federal program and must be revised to reflect changes in the Federal regulations. This approach has caused difficulties for the State during EPA's delay and suspensions in implementing the RCRA program. The regulated community in West Virginia, in commenting on proposed State regulations, has argued that, when there is an absence of Federal regulation due to suspensions, modifications, or delays in effective dates, the State cannot regulate in that area. This group argues that State regulation in areas where no Federal regulations are in effect would be inconsistent with the Federal program. West Virginia was challenged for proposing financial responsibility requirements for hazardous waste facility operators when EPA delayed the effective date of those Federal requirements. Thus, every time a void in regulatory coverage is created by a shift in Federal policy, States like West Virginia could be challenged on the appropriateness of State action in that particular area. If this argument is upheld in the courts, such States will have to wait until Federal policy is established to propose regulations.[144]

The "floor" approach reflects a State statute or policy decision requiring that the State program must be "at least as stringent" as the Federal program. For States with "mirror" or "floor" types of programs, a frequent concern has been that less stringent or relaxed Federal requirements could undercut State program efforts or might threaten State program approval. More stringent State requirements could be viewed as inconsistent with the Federal and other State programs or as a constraint on interstate commerce.

The third type of approach, the "ceiling" approach, can cause problems for implementation of State regulatory programs when there are delays or changes in the Federal program. "Ceiling" approaches generally involve a statutory requirement or policy decision that the State programs must be "no more stringent than the Federal program." Ceiling States are dependent on the adequacy of the Federal rules. Changes in the Federal program, or suspensions of Federal standards, can be disruptive and could bring State program implementation efforts to a halt. To gain Federal approval, the State requirements must be as stringent as the Federal program, but to meet State law, the State regulations may not be more stringent than the Federal program. When finally in place, these programs should be effectively similar to "mirror" States; however, **implementation during a period of frequent changes and reversals in the Federal program might be difficult or impossible.**

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[144] Testimony of Norman Nosenchuck, ASTSWMO, at hearings on RCRA reauthorization before the Subcommittee on Commerce, Transportation, and Tourism, House Committee on Energy and the Environment, 97th Cong., 2d sess., Apr. 21, 1982.

Colorado's hazardous waste statute adopts the "ceiling approach" and requires that the State program be "no more stringent" than the Federal program. Colorado is currently developing a State RCRA program and is operating under cooperative arrangement. When EPA suspended the Federal ban on disposal of liquids in landfills, Colorado was suddenly left without any apparent authority under its State hazardous waste program to stop the planned landfilling of bulk liquids at the Lowry landfill while EPA "reconsidered" the Federal rule. The adequacy of the landfill operation was then under challenge by State and local officials. In response to public criticism, EPA reimposed the Federal ban. The Lowry dump was later ordered to remedy design failures.

North Carolina's "ceiling" provision also requires that State rules be "no more stringent than" the Federal regulations. Following an initial determination by the State Department of Natural Resources that the July 1982 EPA land disposal regulations were not stringent enough, the Governor imposed an emergency moratorium on the new landfill permit applications pending further study and public hearings.[145] If this review indicates that more stringent State land disposal standards are necessary, the State agency will petition the legislature to amend the State law.

Differences Between Federal and State Programs

During the interim authorization period, a State program can receive approval to regulate hazardous waste if the State demonstrates that its program is substantially equivalent to the Federal program and that it has adequate authority and resources to administer and enforce its program. This allows continuation of an existing State program even though it may differ from the Federal program requirements. Without interim authorization, generators, transporters, and treatment, storage, and disposal facilities (TSDFs) would have to comply with both Federal and State requirements. However, once Federal regulations are issued, the State cannot impose less stringent requirements on the same subject matter. Many existing State programs differ from the Federal program in significant ways. Examples of such variations are discussed below based on OTA's contractor surveys and informal communications from State agencies.[146] The primary areas of difference during the interim period are discussed below and in table 74.

Universe of Waste Regulated

The State program provisions for identification and classification of hazardous waste frequently will cover a broader or narrower universe of waste than the Federal program. The State program may include different waste lists or more characteristics for identifying hazardous waste, or its tests for establishing hazardous characteristics may cause more wastes to be included.

California controls a broader universe of waste than the Federal program, including many household, agricultural, and mining

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[145] Hazardous Waste Report, vol. 3, October 1982.

[146] ASTSWMO Survey for OTA; Citizens for a Better Environment, "Approaches to Hazardous Waste Management in Selected States," OTA Working Paper, December 1982; National Conference of State Legislatures, *Hazardous Waste Management: A Survey of State Legislation 1982* (Denver, Colo.: 1982); and Michael S. Baram and J. Raymond Miyares, "Expanding the Policy Options for the Management of Hazardous Wastes," OTA Working Paper, Feb. 1, 1982.

Table 74.—Comparability of State Hazardous Waste Programs to Federal RCRA Program

State	Universe of waste	Generators	Transporters	Facilities
Alabama	RCRA	RCRA	Permit required	RCRA
Alaska	COOPERATIVE ARRANGEMENT			
Arizona	Equivalent, plus expanded reactivity critera	Annual reports Manifest copies to State	RCRA	Proof of financial responsibility; quarterly report
Arkansas	RCRA plus PCBs	RCRA by regulation	Permit and State manifest	RCRA
California	RCRA plus PCBs, metals, waste oil, mining waste, some recycled wastes, and more stringent toxicity criteria	Monthly reports for storage of less than 60 days	Registration, insurance, inspection	No exemptions in general. Special permits for disposal of certain high-hazard waste
Colorado	Some recycled/reused materials covered by RCRA excluded under State law	RCRA by statute	RCRA by statute	Disposal sites revert to State ownership at closure
Connecticut	RCRA by statute	N.E. manifest	License, insurance, bonding for hauler storage	Licenses; special requirements for dewatered sludges
Delaware	RCRA	Annual report, copy of manifest to State	License	Special ground water monitoring requirements
Florida	RCRA by reference	RCRA by reference; generator inspections	RCRA; inspections	RCRA by reference; liability insurance required
Georgia	RCRA by reference	RCRA by reference	RCRA by reference; permit required	RCRA by reference
Hawaii	COOPERATIVE ARRANGEMENT			
Idaho	COOPERATIVE ARRANGEMENT			
Illinois	RCRA plus special wastes, infectious hospital wastes	State manifest tracking system	Permit required; all shipments must be manifested	Prohibits landfilling unless facility has appropriate permit for each waste stream received
Indiana	RCRA	More stringent recycling requirements	Liquid industrial waste haulers must have a permit	RCRA
Iowa	RCRA by reference	RCRA by reference	RCRA by reference	Facility must establish financial responsibility consistent with risk
Kansas	RCRA	Must obtain disposal authorization from State before waste shipment	Registration, insurance; State approval of disposal requests before transport	Waste disposal must be authorized
Kentucky	RCRA by reference	Equivalent	Equivalent	RCRA by reference
Louisiana	RCRA plus State waste list; more stringent toxicity test	State manifest system	Permit required	Each TSDF unit permitted separately; liability insurance required; quarterly reports for onsite disposal
Maine	RCRA	N.E. manifest	License, insurance	Licenses
Maryland	RCRA plus PCBs	RCRA	License	State permit
Massachusetts	RCRA plus waste oil, PCBs and radioactive waste	N.E. manifest	License, bond	License; liability insurance
Michigan	RCRA plus waste oil, additional toxic wastes, recycled wastes must be sold for gain	State manifest system	License	License; certificates of waste disposal, more frequent inspections
Minnesota	RCRA plus waste oil, recycled wastes, additional waste characteristics	Manifest returned to State; generator waste disclosure and management plan.	RCRA	Monthly reports for offsite TSDFs
Mississippi	Equivalent	Equivalent	Equivalent	Equivalent
Missouri	Waste oil, State-listed wastes	Manifest returned to State; generator registration	License, insurance	Similar to RCRA, monthly reports, certification of recyclers
Montana	RCRA	RCRA	RCRA	RCRA
Nebraska	RCRA by reference	RCRA by references	RCRA by reference	Equivalent

Table 74.—Comparability of State Hazardous Waste Programs to Federal RCRA Program—Continued

State	Universe of waste	Generators	Transporters	Facilities
Nevada	.... COOPERATIVE ARRANGEMENT			
New Hampshire	RCRA	N.E. manifest	License and insurance	Permit by rule
New Jersey	RCRA plus waste oil, PCBs, recycled wastes	State manifest; manifest copies to State	License, operating requirements	Monthly ground water monitoring reports
New Mexico	.... COOPERATIVE ARRANGEMENT			
New York	RCRA by statute	—	License	RCRA
North Carolina	RCRA	RCRA by reference	RCRA by reference	RCRA
North Dakota	RCRA	RCRA	RCRA	RCRA
Ohio	RCRA	RCRA	Transporter registration	RCRA
Oklahoma	RCRA plus PCBs, no exemption for recycled wastes	RCRA	Registration, manifest for recycled wastes	RCRA; storage requirements for recyclers
Oregon	No waste listing, regulate by waste characteristics	Manifest exemption for generators shipping less than 2,000 lb/load	RCRA	Substantially equivalent
Pennsylvania	Primary neutralization units	Quarterly reports; manifest to State; must get authorization from TSDF before waste shipment	License	Facility must authorize that it is capable of handling wastes before shipment
Rhode Island	9 waste characteristics	N.E. manifest	License; liability insurance	Licenses; recycling regulated;
South Carolina	No exemption for recyled waste; additional listed wastes; more stringent corrosivity test	Manifest copies to States; must obtain authorization from TSDF before waste shipment	Permit	quarterly reports for onsite TSDFs
South Dakota	.... NO PROGRAM			
Tennessee	Equivalent	Equivalent	Equivalent	Ground water monitoring wells approved by State geologist
Texas	RCRA plus halogenated hydrocarbons	RCRA	RCRA, hauler storage is regulated	RCRA, liability endorsement
Utah	RCRA, waiver for some recycled wastes	RCRA	RCRA	RCRA
Vermont	19 classes of hazardous wastes, additional wastes regulated	N.E. manifest	License	Permit by rule, recovery operations regulated
Virginia	RCRA	RCRA	Permit	RCRA
Washington	Larger universe of waste, mining wastes, and degree of hazard system for extremely hazardous wastes	RCRA	RCRA	Insurance; location restrictions for extremely hazardous waste facilities; buffer zones
West Virginia	.... COOPERATIVE ARRANGEMENT			
Wisconsin	RCRA, more stringent recycling provisions	Manifest to State, annual report	License	License, quarterly report, treatment at wastewater treatment facilities must be permitted
Wyoming	.... NO PROGRAM (EPA PROGRAM OPERATING IN STATE)			

NOTES: RCRA – State program is nearly identical to Federal regulations.
Equivalent – State program is equivalent, but not identical to Federal regulations.
RCRA by reference – State program adopted Federal regulations by reference.
— – not classified.

SOURCES: Robert A. Finlayson, "Should State Rules Be Tougher Than EPA's?" Solid Waste Management, vol. 25, pp. 78, 80-82, May 1982; *Hazardous Waste Regulatory Guide: State Waste Management Programs* (Neenah, Wis.: J. J. Keller & Associates, Inc., 1982); and Citizens for a Better Environment, *Approaches to Hazardous Waste Management in Selected States*, OTA Working Paper, December 1982.

wastes, along with drilling muds, sewage sludge, tannery waste with trivalent chromium, and cement kiln dust. Additionally, States may use methods of identifying hazardous waste that result in more wastes being classified as hazardous. The California waste extraction test, used to determine whether toxic constituents can leach into the environment, is generally considered to be more stringent than the test required by the Federal regulations.

Several States use a "degree-of-hazard" type of waste classification system.[147] California's waste classification scheme distinguishes between "hazardous" and "extremely hazardous" wastes. A separate disposal permit is required for each shipment and disposal of extremely hazardous waste.*

Exclusions and Exemptions From Universe of Waste

Many States have limited the small generator exemption to exclude fewer generators than the Federal exemption.[148] At least 20 states, including 5 of the nation's 10 largest waste generating States, have no small quantity exemption, more stringent requirements with regard to quantity than EPA's exemption, or do not allow hazardous wastes from small generators to be disposed of in sanitary landfills. Half of those States that have the same quantity cutoff as EPA have some form of reporting requirement to keep track of the exempted waste and its disposal, or to limit disposal options. One significant feature of some States limited small generator exemptions is that special provisions may apply to these generators that are not as extensive as for large generators. (Table 75 includes a summary of State small generator provisions.) Several States also include hazardous waste recyclers under State regulatory programs. This is frequently done because the States have experienced hazardous waste problems as the result of "recycling activities."

Licensing or Permitting of Waste Haulers

Special inspection and/or licensing requirements for hazardous waste are imposed in some States. They may also require special training for haulers. California requires permits for each shipment of hazardous waste. Liability insurance or bonding requirements for waste haulers are another common difference from the Federal program.

More Extensive or Detailed Manifest Requirements for Tracking of Hazardous Wastes.

California, New Jersey, and Michigan are examples of States with manifest systems that require more extensive information than the Federal manifest. States may require that the generator, transporter, and disposal facility operator each submit a manifest for the same shipment. This "paper" trail has two advantages: 1) manifesting of all hazardous waste makes any exits from the system more detectable, thus assisting in enforcement, and oversight, and providing an incentive for waste handlers to comply; 2) more extensive manifest information can assist the State in developing waste management plans and regulatory programs, although this aspect has not been implemented extensively in two States where it is used because of budgetary and practical limitations in processing the data.

More Stringent Facility Standards for TSDFs

During interim status and final authorization, States may impose more stringent requirements than the Federal program—e.g., a stricter standard for design of facilities.

By statute, since 1982, New Jersey has required installation of a system for leachate collection, interception, and treatment in all waste disposal facilities. New Jersey also restricts the siting of chemical waste facilities in or near river flood areas.

While recognizing that only certain wastes are technically or economically amenable to

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[147] OTA's technical memorandum on degree of hazard describes other State approaches to degree of of hazard waste classification systems. See U.S. Congress, Office of Technology Assessment, *Nonnuclear Industrial Hazardous Waste, Classifying for Hazard Management—A Technical Memorandum*, OTA-TM-M-9, November 1981.

*A description of the California degree-of-hazard classification system is presented in ch. 3.

[148] State small generator requirements are described more fully in OTA Staff Memorandum, "The RCRA Exemption for Small Volume Generators," July 1982.

Table 75.—Summary of State Small Quantity Generator Provisions

State	Small quantity cutoff	Difference from Federal standard
Alabama	+	May be required to submit plan to Board of Health before T/D (onsite or offsite)
Alaska	100 kg/mo	Lower cutoff
Arizona	+	
Arkansas	+	Disposal in permitted hazardous waste facility
California	None	No small generator exemption
Colorado	+	None
Connecticut	+	1) 100-1,000 kg/mo; A.R. 2) hauler permit
Delaware	+	
Florida	+	No disposal in landfill without approval
Georgia	+	Some wastes classified as "special waste" require special handling under solid waste program
Hawaii	Cooperative arrangement	
Idaho	Cooperative arrangement	
Illinois	100-1,000 kg/mo exempt from all but manifest	All generators must manifest if produce more than 100 kg/mo special waste
Indiana	200 kg/mo	Disposal of small generator waste only in specified landfills
Iowa	+	—
Kansas	+ but manage 100-1,000 kg as regulated	TSDF operator recordkeeping on source, quantity, disposal of waste received
Kentucky	+	Small generators must register with State
Louisiana	Must petition for small generator exemption	Must petition—no plan to approve
Maine	+	Manifest for hazardous waste disposal in licensed hazardous waste facilities
Maryland	+	—
Massachusetts	20 kg/mo	20-1,000 kg/mo must use manifest, licensed hauler and licensed hazardous waste facilities.
Michigan	100 kg/mo	Must use licensed hazardous waste facility
Minnesota	None	Small generator must comply with all requirements except some paperwork
Mississippi	+	Guidelines for facility accepting small generator hazardous wastes
Missouri	100 kg/mo	Lower limit
Montana	+	—
Nebraska	+	Disposal in landfill requires department approval; and compliance with ground and surface water regulations
Nevada	CA	—
New Hampshire	100 kg/mo	Lower limit—requires packing, labeling and proper disposal
New Jersey	100 kg/mo	Lower limit
New Mexico	None	No quantity exemption
New York	1,000 kg/mo for M 100 kg/mo for State reg.	Regulate quantities between 100 and 1,000 kg/mo; A.R. Disposal of hazardous waste at approved TSDF, correct packing, storing, inspection
North Carolina	+	—
North Dakota	+	Approval of department for disposal of other than household quantities
Ohio	+	Must use permitted facility
Oklahoma	+	—
Oregon	Varies by characteristic	Lower cutoff
Pennsylvania	+	None
Rhode Island	200 kg/infectious waste	No small generator exclusion—except infectious waste
South Carolina	100 kg/mo	Lower limit; State approval before disposal
South Dakota	+	Inspection of solid waste facility for small generator disposal
Tennessee	+	Small generator 100-1,000 kg must notify State
Texas	+	Requires written authorization for permitted facility to receive small generator waste
Utah	+	Manifest for all industrial Class I and hazardous waste; A.R. for TSDF
Vermont	220 lb	None
Virginia	+	Lower cutoff; State notification all generators; may require A.R.; disposal in subtitle D facility; requires CBC approval

Table 75.—Summary of State Small Quantity Generator Provisions—Continued

State	Small quantity cutoff	Difference from Federal standard
Washington	Varies by DOH classification	Regulate to 0.18 kg/mo for some waste mixtures
West Virginia	+	Notification and recordkeeping requirements for small generators
Wisconsin	+	> 100 kg/mo must make A.R.; provide results of waste determination; notice of delivery to disposal site operator
Wyoming	—	—
District of Columbia	+	All hazardous waste must be accompanied by manifest (will lower to 100 kg/mo in 1 year)

Key: + Same as EPA rules (1,000/kg)
A.R. Annual Report
CBC Case by Case
DOH Degree of hazard
T/D Treatment/disposal

SOURCE: ATSWMO Survey for OTA (1982); OTA Staff Memorandum, "The RCRA Exemption for Small Volume Generators," July 1982; J. J. Keller & Associates, Inc., *Hazardous Waste Regulatory Guide, State Waste Management Programs*, Neenah, Wis., September 1982.

recycling, detoxification, incineration, or other treatment processes that are generally recognized as alternatives to landfilling, and that even these processes will result in some residues that will be landfilled, several States are moving toward limiting land disposal of certain wastes. These bans are being implemented to encourage the use of alternative treatment and disposal options, to avoid the use of what could become scarce capacity in suitable land disposal facilities, and to reduce hazards to the public and the environment from land disposal.

Standards for generators and hazardous waste TSDFs under State programs have some interesting variations that impose more stringent requirements or incentives to promote alternatives to landfilling. By far the most stringent are the restrictions on land disposal of hazardous wastes. These range from outright bans on certain land disposal practices to requirements that a generator demonstrate that there are no feasible alternatives to landfilling.

New York and California are currently developing limited bans on landfilling of certain hazardous wastes. California's ban is scheduled to be implemented in stages starting in 1983 with restrictions on landfilling of cyanides and toxic metals above certain concentrations, acid wastes, PCBs, and extremely hazardous liquid organic wastes. New York has recently denied two land disposal permits on the ground that the applicants failed to provide adequately for technologies that offer alternatives to landfilling. Alternatives include the requirement of pretreatment of liquids such as neutralization, detoxification, solidification, or encapsulation before land disposal. Michigan bars landfilling of any liquid wastes without some form of pretreatment to solidify the waste or remove it from the waste stream. Governor Thompson of Illinois has announced his intention to reintroduce legislation, which failed in 1982, that would ban landfilling of hazardous waste. (Illinois already has a statutory provision that restricts land disposal of hazardous waste after 1987 unless the generator demonstrates that there is no technologically feasible and/or economically reasonable alternative to landfilling.) Illinois requires a separate waste stream permit for each waste stream received from a generator for each facility in addition to the basic facility permit. Similarly, Arkansas provides that no "high hazard" waste can be landfilled if it could be destroyed by incineration, and further establishes a rebuttable presumption that incineration is feasible unless demonstrated otherwise.

Other more stringent regulatory requirements may consist of more detailed and extensive permit and licensing reviews for land disposal facilities than for recycling or treatment facilities. **New York requires each major facility to prepare a 10-year management plan that would include a description of steps the facility is taking to promote the development and use of alternative technologies to reduce waste volume and toxicity and short- and long-term environmental emissions (air, water, and solid waste).** Michigan requires that construction permit applications for new facilities include an environmental assessment evaluating the effect of the proposed facility on air, water, and other resources, and an environmental failure mode assessment.

New York requires an onsite environmental monitor (State agency inspector) at certain solid waste disposal facilities that pose potentially serious environmental damage or public health threats. The staff and equipment needed for onsite environmental monitors are to be paid by the operator. Depending on the type of facility and the nature of hazard posed, the State could require full-time, part-time, or temporary onsite monitors. Certain facilities would always be required to have monitors, including commercial-secure land burial operations, commercial hazardous waste incinerators, and commercial treatment facilities handling acutely toxic wastes. Some onsite treatment or disposal facilities which manage acutely toxic hazardous waste are also likely to require onsite monitors.

Several States do not vest regulatory responsibility for all aspects of hazardous waste activities in a single agency. In both Texas and California, the administration of the State RCRA program is split between two agencies. In Minnesota, the State Pollution Control Agency shares hazardous waste regulatory authority with the county governments.

Other State Regulatory Programs

EPA does not require that a State enact specific RCRA-type legislation controlling hazardous waste in order to gain program approval. States may obtain authorization based on their regulatory and enforcement powers under any State laws that are adequate to control hazardous waste. States have controlled the management of hazardous wastes or the effects of waste disposal under a variety of laws dealing with solid waste, air and water pollution control, wildlife protection, hazardous substances, siting, land use, and public health and safety. For example, State laws, which may be later incorporated into the EPA authorized State hazardous waste program, may limit the disposal of certain types of hazardous waste, or may limit the disposal or treatment of hazardous wastes in certain areas—such as residential or coastal areas—or within a certain distance of rivers, and other navigable waters or flood zones. State law may require that the generator or facility operator demonstrate that there is no economically and/or technically feasible alternative to land disposal or incineration. State laws may require additional permits for hazardous waste facilities besides those required by RCRA and other applicable Federal permits.

New York is moving to regulate air emissions from the burning of waste oil and hazardous waste mixtures under State air pollution control legislation. California's Air Resources Board monitors the air quality impacts of hazardous waste activities.

Some States have passed special legislation to regulate the selection and approval of sites for new hazardous waste management facilities (see table 76). Some of these siting laws establish siting commissions which are independent of the hazardous waste permitting agency and can impose additional, and more stringent siting and land use controls than the State regulatory program.

Several States are moving toward establishing a preferred hierarchy of hazardous waste management techniques in their siting programs. Minnesota's waste management plan gives highest priority to alternatives to land disposal including: industrial process modification to reduce or eliminate waste generation; recycle, reuse, and recovery methods; and conversion and treatment technologies to reduce the hazard of the waste in the environment. Minnesota also requires the State Waste Management Board to consider technologies for retrievable storage of hazardous waste for later recycling, reuse, recovery, conversion, or treatment. States may require special siting board approval or advanced submittal of waste facility siting proposals for consideration as part of a comprehensive State waste management plan and may condition permit approval on compliance with other legal requirements. These

Table 76.—Summary of State Hazardous Waste Facility Siting Programs

	AZ	CO	CT	FL	GA	IL	IN	IA	KS	KY	ME	MD	MA	MI	MN	NE	NH	NJ	NY	NC	OH	OR	PA	RI	TN	UT	WA	WI
Siting decision by:																												
Existing agency	X									X		X				X						X					X	X
Siting board			X	X	X		X	X	X	X	X	X		X	X			X	X	X	X		X		X	X		
Local group		X				X				X			X				X							X				
Impasse resolved by:																												
State preemption	X		X	X		X	X	X	X	X		X		X	X		X	X		X	X	X	X			X	X	
Mediation arbitration													X											X				X
Local veto		X														X			X									
Financial assurances:																												
Trust funds	X		X	X					X	X				X						X	X	X	X		X			X
Financial responsibility mechanisms		X	X	X	X		X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X		X
Other				X				X		X																		
Other assurances:																												
Inspections	X	X	X	X		X			X	X		X	X	X				X			X	X	X	X	X		X	X
State ownership	X									X		X										X						X
Contingency plans		X		X			X			X		X	X	X				X					X	X				X
Future use restricted	X	X	X				X		X	X			X	X				X		X	X	X	X	X				X
Incentives and compensation:																												
Local taxes or fees		X	X		X		X			X	X		X				X	X		X				X				X
Tax prepayment													X															
Other			X				X											X			X			X				

SOURCES: National Conference of State Legislatures, *Hazardous Waste Management: A Survey of State Legislation, 1982* (Denver, Colo.: 1982); Citizens for a Better Environment, *Approaches to Hazardous Waste Management in Selected States*, OTA Working Paper, December 1982; and OTA Staff research.

may or may not be integrated with RCRA authorized programs. Table 77 summarizes State options to promote alternatives to land disposal of hazardous waste.

Nonregulatory Options for Management of Hazardous Waste

Regulation is one approach to dealing with the problems that hazardous waste pose to human health and the environment. Control over hazardous waste management is established directly through standard setting, permitting, and civil and criminal enforcement. Through direct regulation, costs are internalized. Hazardous waste generators, transporters, and disposers are forced to pay the costs of responsible management of hazardous waste for protection of human health and the environment through compliance with regulatory requirements.

Table 77.—Summary of State Options for Encouraging Alternatives to Land Disposal of Hazardous Waste

State	Fee structures	Tax incentives	Bonds	State ownership	State waste management plan	Regulatory exclusions	Fast track permitting	R&D programs	Land burial restrictions
Alabama	X								
Alaska									
Arizona	X			X					X
Arkansas	X								
California	X				X			X	X
Colorado									
Connecticut	X					X			
Delaware									
Florida	X		X						X
Georgia		X	X	X					
Hawaii									
Idaho									
Illinois	X	X	X					X	X
Indiana	X	X	X			X			
Iowa									
Kansas	X						X		
Kentucky	X			X			X		X
Louisiana	X								
Maine	X								X
Maryland	X			X					
Massachusetts	X				X				X
Michigan	X	X			X				X
Minnesota		X			X		X		
Mississippi	X		X						
Missouri	X	X		X		X			X
Montana									
Nebraska	X	X							
Nevada	X								
New Hampshire	X								
New Jersey	X				X	X		X	
New Mexico									
New York	X	X						X	X
North Carolina	X	X	X	X					
North Dakota									
Ohio	X								
Oklahoma									
Oregon	X	X							
Pennsylvania									X
Rhode Island									
South Carolina	X								X
South Dakota									
Tennessee	X					X			X
Texas						X			X
Utah									
Vermont									
Virginia									
Washington				X					X
West Virginia	X								
Wisconsin	X	X							
Wyoming									

SOURCES: ASTSWMO, Survey for OTA, 1982; Citizens for a Better Environment, "Approaches to Hazardous Waste Management in Selected States," OTA Working Paper, December 1982; National Conference of State Legislatures, *Hazardous Waste Management: A Survey of State Legislation, 1982* (Denver, Colo.: 1982); The Council of State Governments, *Waste Management in the States* (Lexington, Ky.: 1981); Fred C. Hart Associates, Inc. (for EPA), *A Survey of State Fee Systems for Hazardous Waste Management Programs*, EPA contract No. 68-01-5133, May 25, 1982; National Conference of State Legislatures, *A Survey and Analysis of State Policy Options To Encourage Alternatives to Land Disposal of Hazardous Waste* (Denver, Colo.: July 1981); Michael S. Baram and J. Raymond Miyares, "Expanding the Policy Options for the Management of Hazardous Wastes," OTA Working Paper, Feb. 1, 1982; and OTA Staff research.

Other institutional mechanisms can induce hazardous waste handlers to adhere to minimum standards of care and to bear the costs of proper hazardous waste management or to suffer the economic penalties of improper hazardous waste management, thus internalizing costs. Nonregulatory approaches that are in use or under consideration by various States include expanded liability under common law and statutory provisions, insurance requirements, hazardous waste taxes and fees, trust funds, and State superfunds. State hazardous waste facility siting programs discussed previously also have nonregulatory aspects.

These alternative approaches are directed at deterring improper waste management and promoting sound alternative practices by requiring that responsible parties bear the costs of their actions. Direct incentives such as tax exempt financing, preferential treatment of alternative technologies, fast track permitting, State ownership of waste facilities, and State research and development programs are other nonregulatory approaches.

These nonregulatory approaches are independent of the regulatory system. They can serve as an effective and complementary part of a State's comprehensive response to hazardous waste problems.

Liability

Increased liability for hazardous waste activities could encourage more responsible and environmentally sound management practices. Although there are only a few cases in which damages for improper or illegal hazardous waste disposal have been imposed, the legal trends point clearly toward substantial damage awards in future hazardous waste cases. The prospect of significant liability from past and present activities is influencing State and industry action. In the meantime, the legal barriers to winning lawsuits for damages or other relief for the impacts of hazardous waste activities are being lowered through judicial decisions and State legislation.

Government officials, private attorneys, and insurers have one message for generators, transporters, and facility operators: the risks of substantial financial losses from liability for unsafe hazardous waste activities are increasing rapidly. The prudent business manager should take every available action to reduce that risk by initiating better waste handling practices, or by avoiding generating and disposing of hazardous waste where possible, and by planning now to meet any future liability. If increased liability is to be an effective incentive for generators and disposers to seek alternative hazardous waste management options to remove the risks to human health and the environment (and to their financial well-being), it is clear that substantial legal liability must be seen as a probable, costly, and swift result of unsound waste management activities. Recent legal developments have moved in that direction.

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) imposes liability for the costs to government agencies for cleanup, remedial action, and emergency response and for damages to natural resources. Other Federal laws impose fines and punitive damages for violations of regulations or statutory provisions and several recognize citizen suits as alternative enforcement mechanisms. Many States have similar laws. Except for limited coverage under the CERCLA Post-closure Liability Trust Fund, however, damages for injury to private persons or property are not now covered by CERCLA or RCRA. Provisions dealing with liability for injuries to third parties were dropped as part of the compromise to pass CERCLA and were deferred for further study. **The CERCLA 301(e) study group recently recommended adoption of broad tax-based personal injury and property damage compensation measures for hazardous waste activities.**[149]

Lawsuits involving hazardous waste activities can be expected to increase as more sites are discovered and the public awareness of dangers from exposure to hazardous chemicals grows. These lawsuits can seek monetary damages and/or injunctive relief. The amounts sought by private parties in such lawsuits can be staggering. (One class action case involving hazardous waste dumping in Tennessee is seeking damages of $2.5 billion.) Courts can also award punitive and/or exemplary damages in appropriate circumstances. A court order or injunction may compel a responsible party (e.g., a generator, transporter, or facility operator) either to take a specific action (i.e., remove the wastes, clean up the site, provide an alternative water supply, provide long-term health monitoring and care for exposed persons) or to refrain from taking an action (e.g., no more dumping) and to bear all the costs entailed.

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[149] *Injuries and Damages From Hazardous Wastes—Analysis and Improvement of Legal Remedies: A Report to Congress in Compliance with Section 301(e) of the Comprehensive Environmental Response, Liability, and Compensation Act of 1980 (Public Law 96-510) by the Superfund Section 301(e) Study Group,* 97th Cong., 2d sess., 1982, 2 vols (hereafter 301(e) Study Group report).

Theories relied on for recovery for injuries and property damage from hazardous waste management are based on common law causes of action, sometimes expanded by statute, and include negligence, strict liability, nuisance, and trespass.

Legal Remedies for Injuries and Losses From Hazardous Wastes

The traditional common law remedies for personal injuries and property damage are available in hazardous wastes cases.[150] Negligence and strict liability are directed at compensating injuries due to the actions of another. Private nuisance and trespass are intended to protect possessory interests in land against unreasonable interference from the activities of another. Public nuisance actions seek to protect the broader public interest from unreasonable land uses. Each of these theories has aspects that make it an appropriate mechanism for redress in some cases and not in others. In some instances, state statutory provisions have modified or replaced these common law remedies to ease some of the recurring barriers to recovery. Frequently, lawsuits involving hazardous wastes will include several claims reflecting different theories of liability. A consequence is that the court's decision may be based on a blending of the various concepts behind toxic torts and may not give a clear indication of the precise theory invoked to provide recovery.

Negligence.—Negligence is commonly defined as a failure to conform one's conduct to a legally recognized standard or duty of care. An action for negligence is brought to recover compensation for personal injury and for property damage from the negligent party. To prevail in a negligence suit, the plaintiff must prove four elements:

1. the existence of a duty or obligation recognized by the law to conform to the standard of conduct for the protection of others against unreasonable risks;
2. a failure by the defendant to conform his or her conduct to the required standards;
3. a causal connection between the defendant's conduct and a resulting injury to the plaintiff; and
4. an actual injury or loss.[151]

The standard of care by which the defendant's conduct is measured in negligence cases may be established by prior judicial decisions, statute, regulation, or by analogy from other cases with similar circumstances. In negligence cases of first impression, the standard of care will be what the jury believes a reasonable or prudent person would do under similar conditions or circumstances. A generator or facility operator might be held accountable for injuries on the premise that it was negligent not to have investigated the effects of various disposal options available and selected an option reasonably designed to avoid the type of harm suffered by the plaintiff. Alternatively, a generator or operator's failure to warn of the hazards posed by the wastes might be considered negligent, especially if the plaintiff might have avoided the risk had he been aware of it. **Many generators do not dispose of their own wastes, yet they might be held liable for the**

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[150] Those interested in a more detailed discussion of liability theories for damages from hazardous waste activies and of barriers to recovery under these remedies should consult the report of the CERCLA 301(e) study group.

[151] W. Prosser, *Handbook of the Law of Torts*, 143 (4th ed. 1971).

improper disposal actions of the facility to which their wastes were sent for failing to anticipate or take precautions against the negligent actions of others. (The liability provisions in Superfund make generators liable for the Government's cleanup costs for improper or unsafe disposal resulting in release of hazardous substances without regard to fault—i.e. whether or not the generator exercised due care.)

Some formulations of the negligence standard use the concept of a duty to protect others against an "unreasonable risk" of harm. An unreasonable risk is defined as one of such magnitude as to outweigh what the law regards as the utility of the act or the manner in which it is done. In hazardous waste cases, the community's need for hazardous waste disposal might thus be weighed against the requirement to protect against unreasonable risks, and the risks posed by the facility may be found not to be unreasonable. In some States, however, statutory provisions or common law principles have established that violation of certain statutes or regulations constitutes negligence per se.

While recovery under a negligence theory in hazardous waste cases is an available option, establishment of a duty of care is only part of the case. In some jurisdictions, it will be necessary to show that the defendant knew, or should have known, of the risks involved at the time of the disposal because of the legal principle that there is no duty to avoid or warn of unknowable risks. Given the insidious and long-term consequences of hazardous waste disposal, the dangers posed by the defendant's action may not have been foreseeable based on the state of knowledge at the time. Another difficulty in negligence cases, and in most hazardous waste cases, will be the evidentiary problem of proving: 1) a connection between exposure to a particular waste, chemical substance, or mixture and the injury suffered; and 2) that the chemical originated in the defendant's waste or disposal facility. Often the injury and the resulting lawsuit arise many years after the disposal or exposure, thus adding more difficulties in locating parties, witnesses, and establishing a causal connection.

Strict Liability.—Negligence actions are based on the premise that the defendant failed to take reasonable care to protect others, but some activities are so inherently or abnormally dangerous that injuries or losses can occur even when the defendant exercises the utmost care. To deal with such circumstances, the strict liability theory was developed. Under strict liability, anyone who engages in certain risky activities is legally responsible without regard to fault (i.e., strictly liable) for any injuries resulting from those activities. Many of the early cases involved blasting and aerial spraying. Whether hazardous waste management can be seen as one of the categories of activity that are subject to strict liability under common law principles is not yet clear.[152] Several States have by statute imposed strict liability on hazardous waste activities and the standard of liability for cleanup of hazardous waste releases in the Clean Water Act, section 311, and CERCLA cases is strict liability.

There are various formulations of the strict liability standard recognized in American courts. Some jurisdictions hold that strict liability is absolute without regard to the degree of care exercised. Other jurisdictions recognize some limited defenses that allow a balancing of interests. A third formulation bases strict liability on the magnitude of the risks involved and the relative ability of the parties to sustain the risks of loss.[153] Activities covered by strict liability differ from those that are considered as negligence or public nuisance in that they have some social utility, even though a serious risk is imposed which is not a normal incident of everyday life (so that the plaintiff would be unlikely or unable to avoid the risk). Strict liability awards compensation for the injuries and losses suffered. Like negligence, it is invoked "after the fact," i.e., after the injury has occurred. Strict liability eases the plaintiff's burden of proof somewhat by eliminating the need to show "fault" and by limiting available defens[illegible] However, the plaintiff still faces substantial evidentiary problems in demonstrating a causal connection or nexus between the plaintiff's injury and the defendant's hazardous waste activities.

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[152] Strict liability for hazardous waste activities was found in *Department of Transportation* v. *PSC Resources, Inc.*, 175 N.J. Super 447, 419 A2d, 1151 Div. 1980). But a different conclusion was reached in *Elwell* v. *Petro Processors, Inc.*, 364 So. 2d 604 (La. App. 1978), cert. denied, 336 So. 2d 575 (La. 1979).

[153] See 301(e) study group report at 122. See also *New Jersey* v. *Ventron Corp.* 182 N.J. Super. 210 (App. Div. 1981) where current and past owners of a mercury processing plant were held liable for costs of cleaning up the wastes dumped at the site and the contamination of surface waters.

Nuisance.—Nuisance, in essence, is a common law remedy that can be invoked whenever one's use of land unreasonably interferes with another's use and enjoyment of a right. This right may be either a possessory interest in land in private nuisance actions, or a more general right of the public (e.g., to be free from unsafe conditions or from unwarranted air, water, or noise pollution) in public nuisance actions. Public nuisance and private nuisance actions are distinct in origin and in the rights protected. However, in both actions, the courts frequently impose a balancing test that weighs the relative social or economic utility of the activity involved against the rights of or harm suffered by the complaining party. In some hazardous waste cases, this balancing of the equities may recognize the social necessity of hazardous waste facilities and deny or limit the monetary or injunctive relief sought by the plaintiff as abatement of the nuisance.[154]

A **private nuisance** is an unreasonable interference with a person's interest in the private use and enjoyment of land. The person bringing the nuisance action must be the one whose possession of the land is impaired, i.e., the owner or tenant. Private nuisance differs from trespass in that the interference with the use or enjoyment of the property must be unreasonable and significant. Under modern case law, to be unreasonable, the nuisance must be shown to be the result of the defendant's negligent, intentional, or ultrahazardous activities. To be significant interference, it must be more than the consequences of ordinary community activity. The private nuisance theory adopted by the **Restatement (Second) of Torts** would require a court to balance the "gravity of harm" suffered by the plaintiff against the utility of the defendant's conduct in determining whether the conduct was unreasonable.[155]

Nuisance actions have been successfully pursued in environmental pollution cases.[156] Actual damage or harm to the plaintiff's land or a resulting injury need not occur for a nuisance to be found. The threat of personal discomfort or disease from a hazardous waste facility or the prospect of future losses from the impacts of the facility's activities creates an interference with the use and enjoyment of property. This threat is a sufficient basis for the issuance of an injunction requiring removal of the nuisance. Proposed hazardous waste facilities similarly could be enjoined under a theory of prospective nuisance—that the facility if built would cause interference with the plaintiff's use and enjoyment of land.

Nuisance actions are not limited to the person who created the nuisance, (e.g., the facility operator or the anonymous dumper of toxic wastes). An innocent purchaser or owner of land on which an artificial condition creates a nuisance can be held liable if the new owner fails to take action to abate the nuisance within a reasonable period of time after he discovers or should have discovered the condition. Unlike the plaintiff who must be in possession of the land affected, the person who created the nuisance but who transferred or sold the property on which it is located can be sued in a nuisance action.

Public nuisance is defined as an unreasonable interference with a right common to the community at large. The conduct is considered unreasonable and, thus, a nuisance if its utility does not outweigh the gravity of the harm it produces. This test allows a rough balancing of the benefits and burdens from a particular activity. Every state has a statutory provision authorizing suits to abate public nuisance.[157]

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[154] *Boomer* v. *Atlantic Cement Co.*, 72 Misc. 2d 834, 340 N.Y.S. 2d 9 (1972).

[155] *Restatement (Second) of Torts*, §827.

[156] Private nuisance actions are appropriate for the interference with use and enjoyment created by noise, by odors, and other air pollution, by water pollution and the contamination or pollution of subsurface waters. See cases cited by 301(e) study group at 105.

[157] 301(e) study group report, vol. II at 171.

Public nuisance actions differ from private nuisance actions in that the right to be protected is one enjoyed by the public at large and is not tied to interest in publicly owned land. The cause of action arises out of a defendant's unreasonable use of his land for activities that interfere with this public right. Public nuisance actions are commonly brought by public officials, however, many State public nuisance statutes also authorize citizens to bring these actions on behalf of the public. Public nuisance actions are generally directed at obtaining injunctive relief for abatement of the nuisance. Private damages are not usually recoverable by private citizens asserting public nuisance claims unless it can be shown that the damages they have suffered are in addition to and distinct from the general harm to the public interest created by the nuisance. Many State laws make the violation of statute or regulation, such as regulations governing hazardous waste facilities, a public nuisance. A public nuisance case may also require the weighing of equities before finding a nuisance. As in the private nuisance case, the fact that a facility is permitted is not an absolute defense, although it may be raised to show public recognition of the utility of the activity.

A private or public nuisance action can be pursued to enjoin the defendant from entering into an activity that will constitute a nuisance, or from continuing a nuisance already begun, or to seek compensation for the damages suffered. Damages can be recovered for harm or loss to the plaintiff's property and for any personal injuries suffered as a consequence of the nuisance. A single nuisance action may seek more than one remedy.

Generally, a prerequisite to injunctive relief is a finding by the court that the harm to the plaintiff is irreparable, i.e., it cannot be remedied by the payment of compensation. Of course, payment of compensation may not be a complete remedy where the nuisance and its harms are of a continuing nature.

Other remedies may also be fashioned by the court in a nuisance action, such as a combination of damages and an injunction, a delayed injunction, or an order for affirmative action. A delayed injunction, which does not take effect until a specified period of time has passed, may prove useful in developing technology areas, where all possible adverse effects are not known or the technology to minimize potential risks is unavailable at present. The delay could give the defendant an opportunity to consider various alternatives to cure the nuisance. Through the use of a remedy such as the delayed injunction, the courts can effectively bring pressure to force improved technology and to minimize potential risks otherwise imposed by hazardous waste management.[158]

Trespass.—A right of action in trespass arises out of the defendant's interference with the plaintiff's right to the exclusive enjoyment of his property. Originally, under common law, recovery under trespass provisions was absolute upon showing of an actual invasion of the plaintiff's property by the defendant or by an object or substance under the defendant's control. Trespass by environmental pollution would seem to be another possible common law remedy in hazardous waste cases. However, most State courts today require that the invasion be shown to be intentional, negligent, or the result of an ultrahazardous activity or of an abnormal or unreasonable use of property.

Injuries caused by the defendant's negligence or high-risk activities might also be remedied by suing on a negligence or strict liability theory instead of in trespass, since the defendant's conduct is the major factual issue in all three cases. However, in some States, the longer statute of limitations applicable to trespass cases may be advantageous in some circumstances.

A trespass is "intentional" under the general rule adopted in the **Restatement (Second) of Torts** if the defendant acted purposefully to enter, lead, or set an object in motion that almost certainly would come to rest on the plaintiff's property.[159] Except in the case of "midnight dumpers," the plaintiff faces a difficult burden in showing that the defendant intended that toxic waste constituents would migrate onto the plaintiff's property. Intentional action might be shown if the defendant knew or should have known that rain, wind, or surface runoff would carry hazardous substances onto the property. Whether land burial of hazardous substances with subsequent migration of toxic constituents in ground water would be considered an intentional trespass is uncertain. Several commentators have concluded that existing precedent would not support such a finding because it would be difficult to demonstrate: 1) that trespass with ground water transport was an "almost certain" result of land burial and 2) that the defendant knew or should have known of such a probable result.[160]

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[158] In *Village of Wilsonville* v. *SCA Services*, as a result of a public nuisance suit, a State-permitted hazardous waste facility was ordered closed with all wastes to be exhumed and removed from the dump site, and the site decontaminated. Compliance with the site closure and cleanup order was phased to allow completion of necessary preparation studies. 77 Ill. App. 3d 618, 396 N.E. 2d 552 (1979), aff'd No. 10052885 (Ill. May 22, 1981).

Trespass actions can result in a court order barring further trespass and requiring removal of the invasion and/or the recovery of damages for injuries or property loss resulting from the invasion. There have been trespass cases involving air and water pollution where substances have migrated onto the plaintiff's property from the defendant's activities.[161] A major difficulty in trespass actions in some jurisdictions is that the courts have not recognized a landowners's right to pure, uncontaminated percolating ground water, so that even if an intentional invasion were shown, it might not result in liability. As in private nuisance actions, trespass cases require that the complaining party be in possession of the property affected. In trespass, there is no balancing of the plaintiff's exclusive right to the use and enjoyment of his property against the social utility of the defendants activity or the relative costs to the parties.

Barriers to Recovery.—In bringing these actions, plaintiffs face many procedural and evidentiary problems. There are, as well, substantial difficulties in gaining expansion of established legal theories to cover hazardous waste cases, although a clear trend exists. Among the common problems that are anticipated in these cases are the statute of limitations, proof of causation, identification of responsible parties, and the availability of such theories as joint and several liability, or enterprise liability in cases involving multiple defendants.

Statute of limitations: The local rule that lawsuits must be filed within a specified period of time after the act that caused the harm, or the discovery of the injury, can pose a barrier to private damage actions involving long-term chemical exposure, abandoned waste sites, diseases with long latency periods, or situations where contamination of hazardous waste is not readily apparent. In such cases, victims may be barred from filing a lawsuit before they are even aware of their injuries. This difficulty is reduced somewhat in States that have adopted a discovery rule that starts the period during which a lawsuit must be filed when the plaintiff discovers the injury.[162]

Proof of causation: The Superfund section 301(e) study group concluded that the burden on the plaintiff of proving that the injuries suffered were the result of the defendant's conduct may be a formidable problem in suits involving hazardous waste.[163] Developing the evidence necessary to demonstrate liability may involve expensive and detailed scientific testing and presenting of expert testimony in several different fields. The costs of preparing a successful case may be so steep that only those cases involving potentially high damage awards would warrant incurring the expense under the prevailing practice of contingent fee arrangements for the plaintiff's attorneys.

Identification of responsible parties: In some cases, the victims may encounter difficulty in determining which parties to sue. Where the possible defendants can be identified, many years may have elapsed since waste disposal.

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[159] *Restatement (Second) of Torts,* §§158, 165 (1965).

[160] David, "Groundwater Pollution: Case Law Theories for Relief" 30 MO. L. Rev. 117 (1974); Davis, "Theories of Water Pollution Litigation," 1971 Wisc. L. Rev. 738; *Phillips* v. *Sun Oil Co.*, 307 N.Y. 328, 121 N.E. 2d 249 (1954).

[161] See 301(e) study group report at 101-104.

[162] The 301(e) study group report at 43-45. The report notes that 39 jurisdictions have adopted some form of the discovery rule either by statute or judicial interpretation at 133 n.4.

[163] The 301(e) study group report at 69-71.

The whereabouts of facility operators or generators may be unknown, and companies may have changed ownership or may have gone out of business. In other cases it may be difficult to ascertain the original wastes or their sources so as to identify the responsible generators.

Joint and Several Liability/Enterprise Liability.—The availability to plaintiffs and to potentially responsible parties of theories that can be used to apportion fault and liability for damages among a group of defendants can be of some advantage in hazardous waste cases when the responsible party cannot be distinguished from other group members under the evidence available or when several defendants contributed to the situation causing the injury. These theories can slightly ease the plaintiff's burden of proof and can expand the pool of responsible parties from which damages can be recovered.

Insurance

Relevance to Waste Management

Insurance is one of the oldest and most commonly used techniques for dealing with risks. Today, there are several different types of insurance coverage available to hazardous waste firms. Comprehensive General Liability Insurance Policies offer full coverage for sudden and accidental pollution on an "occurrence" basis (i.e., covering all claims arising from events occurring during the policy year whenever the claim is filed). Environmental Impairment Insurance offers coverage for nonsudden pollution incidents on a "claims made" basis (covering all claims made in the policy year without respect to when the incident causing them occurred). A third type of coverage, currently available only to generators in the chemical industry, combines coverage for sudden and nonsudden pollution incidents in a single comprehensive contract on a claims made basis. Because of the lack of loss experience and the relative infancy of risk assessment in the hazardous waste management area, insurers are likely to move increasingly to the use of claims made policies for hazardous waste activities.

The impact of insurance depends largely on the underlying rule of liability and the terms and availability of coverage. Payment of settlements and damage awards to injured parties is made part of a hazardous waste facility's ongoing operating costs through liability insurance coverage. Premiums for liability coverage are tied, to some extent, to the loss experience of the particular facility, and thus tort actions are a form of economic incentive to avoid health and safety risks that may produce a poor loss experience and ultimately higher premiums. To the extent that premiums are experience-rated, it is generally believed that facility owners and operators will seek to minimize the sum of the cost of safety measures, insurance costs, and uncovered liability costs.

The availability and price structure of insurance coverage may create significant incentives for management to act affirmatively to avoid losses due to environmental contamination. While such losses may be covered by insurance and therefore may not be incurred initially by the insured party, such claims will substantially increase premiums, and loss avoidance can become economically preferable. Reliance on an insurance mechanism assumes that a private sector business will provide valuable oversight of its hazardous waste activities, through routine inspection, monitoring, and risk evaluation, as well as eventually through attempts to minimize premiums, in the task of managing the risks from those activities. But insurers generally have been wary of proposals that would cast them in the role of surrogate regulators.

If insurance brings about the results expected in theory, it can be a strong incentive to achieve some of the goals that otherwise would have to be achieved solely through "command and control" regulation. Insurance requirements under RCRA, CERCLA, and State programs can be seen as complementary to the regulatory requirements.

On the other hand, insurance can blunt the incentives created by other regulatory and nonregulatory approaches to risk management.

Insurance spreads hazardous waste risks over time, and across the industry among like situated firms and facilities. This spreading may tend, in particular cases, to decrease the economic incentive to avoid health, safety, and environmental risks among individual generators, transporters, and facility owners and operators, unless they are somehow convinced that others are undertaking similar avoidance measures.

Overall, the impact of insurance on the risk management decision is an ambivalent one: Without insurance, the existing regulatory or nonregulatory incentives have little practical impact on judgment-proof parties. Insurance makes available an amount of money to be used to respond to adverse judgments. Insurance compensation to victims of hazardous waste activities often can be made without resort to the courts, thus avoiding the delay, costs, and evidentiary burdens facing the plaintiffs in liability actions. Moreover, judgments requiring abatement of or compensation for the adverse impacts of hazardous waste activities would lose their effectiveness as an incentive for better waste management if generators, transporters, or facility operators could avoid the financial consequences by simply going out of business.

For insurance to operate as an effective and complementary mechanism in the existing Federal and State system: 1) insurance coverage for hazardous waste activities must be available and affordable; 2) the level and scope of coverage must be adequate for the magnitude of risks insured; 3) the coverage must continue after closure of the facility; and 4) more consistent and perhaps standardized risk assessment procedures must be used.

EPA financial responsibility requirements for hazardous waste treatment, storage, and disposal facilities require certain minimum levels of liability coverage either through an insurance policy or self-insurance. EPA is currently considering whether to promulgate rules for additional financial responsibility requirements for corrective action at land disposal facilities.

Fees, Taxes, and Other Economic Incentives to Encourage Alternatives to Land Disposal

One of the key assumptions in setting up a national regulatory program to deal with hazardous wastes was that as the program was implemented, hazardous waste disposal costs would rise significantly. It would then become economically attractive for generators to adopt new processes and to seek alternatives to land disposal. Preliminary economic analyses of the cost impacts of the RCRA regulations, however, appear to indicate that while the costs of compliance are significant, the cost increases are not of such magnitude as to create a substantial economic incentive to shift to other disposal and treatment alternatives. By far the most significant impact of the interim status standards for land disposal operations was the requirement to install a ground water monitoring system, but the cost per unit of waste deposited varied significantly depending on the size of the facility. EPA's analysis of the cost impacts of the final land disposal rules indicate that primary impacts will fall on small onsite landfills and small surface impoundments, and that significant economies of scale will dilute the initial economic impacts at large commercial landfills.[164] Potentially, the most substantial cost component of the July 1982 land disposal regulations is corrective action (ground water pumping and cleanup). However, currently there is no requirement for operators to demonstrate their financial capability to carry out corrective actions to receive such a permit.

Because it is now apparent that increased regulatory compliance costs alone might not be significant enough to induce a change in disposal practices, many States are studying the effectiveness of various financial incentives to influence hazardous waste management activities. Among the most typical approaches are fees, taxes, and direct financial or technical assistance to preferred management technologies. Table 78 summarizes State fee mechanisms; table 79 shows availability of tax incentives and bonds.

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[164] See discussion of regulatory impact analysis in the preamble to the land disposal regulations, 47 F.R. 32,337-32,348, at 32,342, July 26, 1982.

Table 78.—State Fee Mechanisms

	Facilities	Transporters	Generators
Alabama	T	—	T
Alaska	—	—	—
Arizona	—	—	—
Arkansas	P,A,M	B	—
California	T,F	V,B,I	T
Colorado	—	—	—
Connecticut	—	—	G
Delaware	—	—	—
Florida	S	—	G,T
Georgia	—	—	—
Hawaii	P	—	—
Idaho	—	—	—
Illinois	T	—	T
Indiana	T	V,B	—
Iowa	—	—	—
Kansas	P,T	—	T
Kentucky	P,A,M	—	R,G
Louisiana	P,A	—	—
Maine	P,A,M	O	G
Maryland	P,A	—	—
Massachusetts	P	V	—
Michigan	P,A	V	—
Minnesota	—	—	—
Mississippi	T	—	T
Missouri	P,A,T	V	T,G
Montana	—	—	—
Nebraska	—	—	—
Nevada	—	—	—
New Hampshire	P,A	B	—
New Jersey	P,M,T	V	T
New Mexico	S	—	—
New York	—	—	—
North Carolina	F	—	—
North Dakota	—	—	—
Ohio	P,A	V,B	T
Oklahoma	—	—	—
Oregon	P,M	—	—
Pennsylvania	—	—	—
Rhode Island	P,A	V	—
South Carolina	—	—	—
South Dakota	—	—	—
Tennessee	P,A	Q	—
Texas	—	—	—
Utah	—	—	—
Vermont	—	—	—
Virginia	—	—	—
Washington	—	—	—
West Virginia	P,A	—	—
Wisconsin	P,A	—	—
Wyoming	—	—	—

Key: A = annual registration/other periodic fee
B = base
F = facility fee
G = generator fee
I = inspection
M = monitoring/surveillance fee
O = other
P = permit application fee
Q = quantity
R = registration
S = surcharge
T = tipping fee
V = vehicle registration

SOURCES: ASTSWMO, Survey for OTA, 1982; Citizens for a Better Environment, "Approaches to Hazardous Waste Management in Selected States," OTA Working Paper, December 1982; National Conference of State Legislatures, *Hazardous Waste Management: A Survey of State Legislation 1982* (Denver, Colo.: 1982); The Council of State Governments, *Waste Management in the States* (Lexington, Ky.: 1981); Fred C. Hart Association, Inc. (for EPA), *A Survey of State Fee Systems for Hazardous Waste Management Programs*, EPA contract No. 68-01-5133, May 25, 1982; and National Conference of State Legislatures, *A Survey and Analysis of State Policy Options To Encourage Alternatives to Land Disposal of Hazardous Waste* (Denver, Colo.: July 1981).

The creation of an economic incentive may be only part of the reason for a State adopting such an option. Some fees may be imposed to deter land disposal and, additionally, to pay for administering the regulatory system, or to provide funds for research and development of alternatives, or for the State superfund for site cleanups and victim compensation.

Facility Fees

A substantial number of States impose a fee or tax of some kind on hazardous waste treatment, storage, and disposal facilities. There is, as would be expected, a wide variation in the types and applicability of these charges and in the disposition of the proceeds. Among the different types of fees imposed are administrative fees for permit applications, licenses, inspections, and similar government requirements, and tipping fees or surcharges levied on wastes received at facilities **which may or may not be passed on to the generator.**

Administrative Fees

These fees range from minimal charges to assessments that are intended to reimburse the agency for the full cost of administering its programs. There are three types of administrative fees for facilities: permit application fees or charges for filing an initial application or permit modification; permit renewal or annual operating fees or other fees assessed on a periodic basis for operating facilities; and monitoring or surveillance fees assessed for site inspection visits or monitoring which may be required as a condition of a permit.

The basis for these fees varies. For example, some States impose fees only on offsite facilities or exempt recyclers. State fees on hazardous waste facilities are set on one or more of the following criteria:

- base fee—minimum charge with no variation among facilities;
- onsite and offsite facilities;
- commercial or noncommercial facilities;
- size of the facility measured by capacity, number of units, or the area of the site;
- facility waste management category, i.e., treatment, storage, disposal, or recycling;

Table 79.—State Fee Revenues (as of Apr. 1, 1982)

State	FY 1982 Hazardous Waste Program Budget		FY 1982 RCRA Hazardous Waste Program fee		
	Total	State share	Revenue collected	As a percent of total program budget	As a percent of state matching share
Arkansas	$347,669	$65,777	$20,000	6%	30%
California	7,686,012	4,384,628	4,384,628[a]	57	100
Hawaii	97,500	15,000	Very minor	Very minor	Very minor
Indiana	1,172,587	293,147	Not collected yet	0	0
Kansas	504,100	135,000	80,000	16	59
Kentucky	872,883	149,805	87,000[b]	10	58
Louisiana	2,000,000	960,000	900,000	45	94
Maryland	564,000	300,000	300,000	53	100
Massachusetts	1,547,000	803,000	18,000	1	2
Michigan	2,277,664	569,632	†	†	†
Missouri	797,082	147,082	208,100	26	100
New Hampshire	531,000	325,000	†	†	†
New Jersey	1,981,929	740,520	200,000[c]	†	†
Ohio	3,123,540	953,592	558,000[b]	18	59
Oregon	599,285	127,211	76,128	13	60
Puerto Rico	720,302	233,827	Insignificant	Insignificant	Insignificant
Rhode Island	271,884	235,000	Not collected yet	0	0
Tennessee	1,839,000	768,000	495,000[d]	27	64
West Virginia	792,000	198,000	†	†	†
Wisconsin	1,055,300	263,843	70,000[e]	7	27

†Data not available.

[a] Agency budget proposed for next fiscal year includes expected fee revenue of $7.8 million.

[b] Annualized estimate.

[c] Includes solid waste fee revenue.

[d] No fees collected yet. This is the expected revenue for the fiscal year with collections starting in April 1982. In fiscal year 1983 the portion funded by fees is expected to increase to 40 percent of total program funding.

[e] No fees collected yet. Expected yearly hazardous waste revenues.

SOURCES: NGA/ASTSWMO Survey, March 1982; Fred C. Hart & Associates, Inc. (for EPA), *A Survey of State Fee Systems for Hazardous Waste Management Programs*, U.S. EPA contract No. 68-01-5133, May 25, 1982; reprinted in *Hazardous Waste Report*, vol. 3, Sept. 6, 1982.

- waste handling technology used at the facility: landfills, deep well injection, land application, incineration, surface impoundment, chemical or biological treatment; and
- volume or quantity of wastes received or disposed of at the facility.

Transporter Fees.—At least 14 States levy fees on hazardous waste transporters. Transporter fees are generally imposed as **vehicle fees** (a charge on each vehicle used to haul hazardous waste), **base fees** (generally levied on each firm engaged in hauling hazardous waste), or some **other type** of fees. Three States utilize other types of transporter fees. Maine charges transporters an import fee on waste generated in other States. Tennessee bases its fee on the amount of wastes transported. California charges an annual inspection fee for waste haulers.

Generator Fees.—California, Kentucky, Missouri, Florida, and Ohio impose generator fees. These States use three different types of fees: tipping registration, and waste generation.

Tipping Fees.—Tipping fees are charges assessed on the receipt of waste at a facility. They are considered generator fees because they are paid either directly by the generator or by the facility operator. In the latter instance, the facility collects the fees "as a trustee of the State" and forwards the receipts to the State agency. Tipping fees in the form of surcharges are imposed at facilities where the generator pays a charge for waste. These surcharge fees may exempt onsite disposal operations where no fee is paid.

Registration Fees.—Kentucky requires generators to pay an annual registration fee based on the amount of hazardous waste to be generated. Besides providing a source of revenue, this type of charge can provide reasonably accurate data on waste generation in a State. Such information helps with receipt projections from other fees as well as other aspects of the program.

Waste Generation Fee.—This type of fee is a tax on hazardous waste generation. It is assessed directly on the generator. Missouri sets a $1 per tonne charge with a maximum annual assessment of $10,000.

Other Tax Mechanisms

As an alternative to the negative economic incentives of imposing fees and taxes to increase the costs of hazardous waste disposal, some States use positive economic mechanisms such as tax incentives and financial assistance to encourage proper waste disposal practices and the development of alternative management technologies. For example, several States provide for limited tax exemptions or credits for business equipment and real estate taxes for pollution control equipment or hazardous waste treatment facilities. By excluding the facility from payment of higher taxes, a benefit is bestowed. Accelerated depreciation is another tax device to give favored treatment to hazardous waste technologies. Other States allow use of tax-exempt bonds as financing for the development and construction of hazardous waste facilities. Some States favor alternative treatment technologies such as recycling or incinerators over land disposal facilities in their tax incentive programs.

Use of Fee Revenues

Proceeds from these fees can be put to various uses. The fees can be deposited to a special account to fund agency hazardous waste regulatory activities, deposited to general revenues, or deposited to a special fund for a designated use (e.g., as for cleaning up abandoned sites or sponsoring research and development on alternative waste management technologies.)

While there appear to be a variety of fee mechanisms available to and used by States, the amounts reported by States as generated through this mechanism in most instances are relatively small compared to funding needs. Fees, however, are an appealing source of revenue for State programs in a time of declining Federal grants (see table 79). **Considering the amount of money received and the various restrictions on its use, it is clear that fees alone are not currently adequate to meet State revenue needs for enforcing hazardous waste programs.**

At a time of increasing regulatory activity, and with the prospect of declining Federal contributions, the significant limitations in reliance on existing State fee mechanisms include the following:

- The administrative fees frequently do not cover full agency costs and would have to be raised substantially if they were used to sustain agency activities. (A permit application of $5,000 or even $25,000 may not cover the costs of technical review and hearings for a large landfill facility.)
- Fee generation may not provide a stable, predictable source of revenue. Fees based on administrative procedures are dependent on a flow of permit applications and renewals. Value and quantity fees are subject to fluctuations in business cycles.

  The schedule of costs may not be tailored to different types of facilities; thus the fee charged might not be proportionate to the administrative costs incurred (e.g., onsite storage tanks may not require the same level of attention as a commercial landfill).
- The State government structure may limit the imposition or use of certain fees through statutory or constitutional provisions. In such instances, the ability of States to respond quickly to reduced Federal grants by promptly imposing or raising fees may be significantly constrained by State law or constitutional considerations, such as biannual meetings of the legislature or the inability to obtain passage of the required legislation. Michigan's fee structure to fund its waste facility and closure fund was held unconstitutional because the fee was not high enough to cover the costs of potential post-closure liability.
- The fees may already be dedicated to another major State program, such as cleanup of existing or abandoned hazard-

ous waste sites or compensation of victims of hazardous waste activities. Using the fees to finance the regulatory program would detract from other efforts.

State "Superfunds"

Many States have enacted laws which are similar to CERCLA that provide for emergency response and cleanup for hazardous substance releases. These State trust funds may be financed from special State taxes, from fees assessed on hazardous waste generators, transporters, and facility operators, or may include State general revenues appropriations.

At least two State funds, California and New Jersey, provide for the compensation of victims of hazardous waste activities. These States then can proceed against the responsible parties for reimbursement of any compensation paid to "innocent" victims. Table 80 summarizes the availability and scope of State superfunds for hazardous waste cleanups.

One of the unresolved issues involving coordination of State superfund and CERCLA cleanups is the extent of the limitation in CERCLA on State taxes that duplicate the oil and chemical taxes in CERCLA. Some industry groups have argued that section 114(c) limits the use of State superfund monies as the State's contributing share in CERCLA cleanups because the State taxes would then be imposed for the same purpose as Federal Superfund taxes. In a case challenging New Jersey's tax on chemical and oil products, the Federal courts deferred to State court jurisdiction. The State courts interpretating State law have concluded that New Jersey's tax is not in conflict with section 114(c) of CERCLA.

In addition to imposing a tax financing a trust fund mechanism for cleanup of hazardous waste dumps, at least 15 States have created statutory provisions concerning liability for cleanup costs for those who cause or contribute to hazardous waste dumps that must be cleaned up. The extent of liability and conditions for recovery actions vary significantly among the States.[165]

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[165] For a more exhaustive discussion see 301(e) study group report vol. II and the NSCL report, *Hazardous Waste Management in the States, 1982.*

Part III: Implementation Issues of the Current Regulatory System

Technology Development and Environmental Protection

Because Subtitle C of the Resource Recovery and Reclamation Act (RCRA) is primarily directed at controlling hazardous waste at disposal, the point where the waste enters the environment, little attention is given to reducing the amount of waste at the source of generation. Subtitle C focuses on establishing proper operating standards for treatment, storage, and disposal facilities (TSDFs). Other provisions of RCRA authorize research and development and informational activities to promote recycling, resource recovery, and waste reduction. However, these programs have largely been underfunded and ineffective in dealing with hazardous waste problems. The Environmental Protection Agency (EPA) solid and hazardous waste programs contain only a few incentives to encourage the use or development of recycling and recovery techniques, source reduction methods, or other techniques to reduce the hazardous characteristics of the waste. **Overall, the effects of the current regulations continue to favor disposal technologies, particularly landfilling, over other waste management options.**

The Clean Air Act (CAA) and the Clean Water Act (CWA), impose technology-forcing standards on industrial polluters, thus stimulating generator participation in the development of effective control strategies. In contrast, RCRA standards for hazardous waste generators require only waste identification, maintenance of certain records and reports, and proper packing, labeling, and manifesting of wastes

Table 80.—Summary of State Superfund Legislation

State	*Fund financing:*								*Uses of fund:*												
	Facility fee tax	Generator fee tax	Transporter fee tax	Appropriations	Bonds	Cost reimbursement	Penalties/fines	Other	Program administration	Emergency response	Spill cleanup	Abandoned site cleanup	Facility closure	Perpetual care	Site/resource reclamation	Equipment, training	Health effects & other studies	Victim compensation	State Superfund share	*Fund limits*	*Responsible party liability*
Alabama		X					X		X					X							
Alaska																					
Arizona				X															X	X	
Arkansas							X														
California		X					X	X							X	X	X	X	X	X	X
Colorado				X				X	X	X										X	
Connecticut	X	X					X				X	X					X		X	X	X
Delaware																					
Florida	X	X		X		X	X	X		X		X			X			X		X	X
Georgia					X					X		X		X	X						
Hawaii																					
Idaho																					
Illinois		X								X							X			X	
Indiana		X								X						X				X	
Iowa																					
Kansas		X								X		X			X						X
Kentucky		X								X		X		X						X	X
Louisiana	X			X	X	X	X	X		X		X		X					X	X	X
Maine	X	X	X	X						X						X				X	X
Maryland	X			X						X					X						
Massachusetts	X			X		X	X			X	X										X
Michigan	X			X	X					X				X						X	X
Minnesota																					
Mississippi																					
Missouri	X	X	X	X				X	X	X		X									
Montana																					
Nebraska																					
Nevada	X			X			X	X		X											X
New Hampshire		X		X			X		X	X				X		X				X	X
New Jersey	X	X			X		X		X	X	X	X			X			X		X	X
New Mexico				X		X				X											
New York	X	X		X			X			X		X			X		X		X	X	
North Carolina	X			X		X	X	X			X	X									X
North Dakota						X															
Ohio	X						X	X	X	X		X	X		X		X			X	X
Oklahoma				X												X					
Oregon	X								X												
Pennsylvania					X		X			X											
Rhode Island																					
South Carolina	X	X																		X	X
South Dakota																					
Tennessee	X				X					X				X	X						
Texas				X				X											X		
Utah																					
Vermont																					
Virginia																					
Washington																					
West Virginia																					
Wisconsin	X			X		X				X				X	X	X				X	
Wyoming																					

SOURCES: National Conference of State Legislatures, *Hazardous Waste Management: A Survey of State Legislation, 1982* (Denver, Colo.: 1982); The Council of State Governments, *Waste Management in the States* (Lexington, Ky.: 1981); National Conference of State Legislatures, *A Survey and Analysis of State Policy Options to Encourage Alternatives to Land Disposal of Hazardous Waste* (Denver, Colo.: July 1981); and OTA Staff research.

before shipment offsite. This difference in environmental regulatory schemes between RCRA, CAA, and CWA is in part explained by the fact that disposal of hazardous solid waste does not necessarily occur at the place it is generated; thus, to control the environmental effects of hazardous waste disposal, it was not necessary to impose standards or limits on the amount of hazardous waste generated.

In considering passage of RCRA, Congress was concerned that such limits on waste generation might prove to be a complex, and perhaps unworkable, strategy with the potential for inordinate disruption of industrial activities. Recognizing that generation of solid and hazardous waste is an unavoidable consequence of a modern industrial society, Congress opted instead for a longer term, indirect strategy. By significantly increasing the costs of waste disposal through regulation of waste facilities, industrial generators would be pressured to reduce their output of hazardous waste and to promote development of alternative waste treatment technologies.

Recycling and Resource Recovery Technology

EPA has relied primarily on various exemptions and exclusions from hazardous waste regulations to promote recycling and resource recovery activities. This approach has been criticized as an insufficient incentive for recycling and also for providing inadequate protection against mishandling of such waste. EPA is considering further changes in RCRA regulations that would exclude some recoverable waste materials from being classified as solid waste, if the waste is reclaimed and used onsite as process feedstock.[166] In contrast, no exclusion would be made if the waste is sent offsite to another firm which reclaims the material for use as feedstock, or if the process waste is not **used** by the firm that **recovers** it, or if the waste is first stored onsite and then reclaimed. Without this exclusion, the material is considered as solid waste and potentially hazardous waste subject to subtitle C regulations. EPA would also reclassify waste burned as fuel, or as a component of fuel, as solid waste subject to RCRA regulations. A maximum period for onsite accumulation of reclaimable materials would be set, and reclamation of a significant portion of the waste would be required annually to qualify for the exemption. Although the approach is not without its problems, it would significantly extend the period of time that hazardous waste could be held. It might promote increased generator efforts at reducing the amount of hazardous waste produced. Offsite or commercial recycling activities and the burning of waste as fuel would be subject to RCRA regulations and, where appropriate, standards would be set for recycling facilities.

The suggested changes exempting generator recycling activities could have serious consequences for some commercial hazardous waste facilities that derive a substantial portion of their revenues from the sale of materials reclaimed from solid and hazardous waste. These commercial facilities will continue to be required to meet RCRA regulations for operation and storage permits for recycled wastes, and it could be difficult for them to maintain a competitive position in the market in reclaimed materials.

Land Disposal Regulations

On July 26, 1982, EPA published interim final regulations for permitting land disposal facilities (landfills, surface impoundments, waste piles, and land treatment units).[167] EPA developed a two-tiered strategy in these regulations.

1. a **liquids management strategy** to minimize the formation of leachate and to contain the hazardous waste constituents in appropriately designed facilities; and
2. a **ground water protection and response strategy** consisting of monitoring to detect and track any migration of hazardous constituents if the facilities fail to contain the waste, and corrective action to remove the contaminants from ground water if certain specified concentration levels are exceeded.

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[166] 47 F.R. 55,500, at 55,584, Dec. 13, 1982.

[167] 47 F.R. 32,274-32,388.

Given the inadequacy and uncertainties about current containment designs, such a two-tiered approach presents substantial problems. EPA's strategy focuses on the effectiveness of remedial action once contamination has occurred, rather than preventive measures for protecting human health and the environment. There is only limited experience in cleaning ground water and soils contaminated with industrial hazardous waste. Moreover, EPA's monitoring requirements may not result in collection of adequate data for identifying ground water contamination. If land disposal of all hazard levels of wastes is allowed to continue (as the July 1982 rules seem to allow), it is essential that a rigorous monitoring program be implemented at all such facilities. Without it there can be little assurance that exposure of humans and ecosystems to hazardous constituents will be prevented through early detection and prompt corrective action.

Analysis of the design technology used in land disposal facilities (presented in ch. 5) indicates that current technology cannot assure complete containment of hazardous waste constituents. EPA has also acknowledged that all land disposal sites eventually will release mobile constituents to the environment. Some of the technical difficulties associated with land disposal containment strategies are summarized below.

1. Studies of existing landfills that incorporated the designs suggested by EPA indicate that leakage will occur. The causes of these liner failures have been attributed to one or more design, construction, or operation errors. No state-of-the-art technology landfill design can be considered as providing an absolutely secure containment system over many decades. Additional in situ and ambient monitoring of new and existing facilities is necessary to evaluate their performance.
2. There is little long-term operating experience with liner and cover materials. All liner materials are vulnerable to failures that increase the rate of liquid migration through the liner.
3. Current experience suggests that few failures of liners in landfill facilities can be repaired; rather, corrective action often must be used to reduce the effects of environmental contaminiation.
4. The fate of constituents released from a facility is uncertain. Some may become immobilized in soil; others may migrate and be incorporated in food and water sources. An adequately designed monitoring system is thus an essential element of any protection strategy to detect contamination promptly and to assist in the formulation of effective remedial measures.

Major Criticism of the Land Disposal Regulations.—OTA has surveyed several reviews of these regulations made by various groups.[168] Several points of concern are common to all.

A general criticism made by environmental groups, citizen groups, academics, and industry is that the regulations use very general performance standards rather numerical performance standards or specific design standards. This was done to promote flexibility in the permit process so that specifications could be developed for each facility. **This approach places a very significant burden on the permit writer to determine whether a particular facility provides adequate protection of human health and the environment.** While most environmental regulatory strategies require some exercise of judgment by the permit writer, the EPA land disposal regulations do so to an unusual degree. The general performance standards do not provide objective guidelines against which to judge the adequacy of a facility. Without these guidelines, facility operators cannot anticipate what will be required of them for permitting, and key decisions about the sufficiency of particular land disposal permit applications will be left to the judgment of the permit writers. This is a critical problem as the availability of necessary technical expertise (e.g., in ground water monitoring, corrective action, and risk assessment) is limited throughout the Nation. **This situation can lead to uneven interpretation and enforcement standards of the land disposal.** The effectiveness of public participation in permitting is also diminished because concerned citizens have little guidance as to the adequacy of the facility's design and operation specifications or the appropriateness of the permit writer's interpretation.

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[168] David Burmaster, "Critique of the Monitoring Provisions in EPA's Interim Final Regulations for Hazardous Waste Landfills," OTA Working Paper, Oct. 18, 1982; Environmental Defense Fund (EDF), "Comments on the Interim Final Hazardous Waste Land Disposal Regulations," Nov. 23, 1982; League of Women Voters of the United States, letter to Rita Lavelle, Oct. 5, 1982; testimony before the Subcommittee on Natural Resources, Agriculture Research and Environment of the House Committee on Science and Technology, Nov. 30, 1982; K. W. Brown, Texas A&M University; H. Johnson, National Solid Waste Management Association; D. W. Miller, Geraghty & Miller, Inc.; N. V. Mossholder, Stablex Corp.; P. A. Palmer, Chemical Manufacturers Association, H. C. Robinson, Hazardous Waste Treatment Council.

The land disposal regulations allow waivers and exemptions from certain performance standards to be made by the permitting authority if there is a lower potential for exposure to hazardous wastes or their constituents. The regulations do not require that more stringent permit conditions be added for management of more hazardous materials or for those situations with potentially high risk to human health and the environment, although the preamble suggests that the permit writer could impose such stipulations upon consideration of the hazard levels of the wastes and the specific site conditions.

The regulations provide that land disposal facilities are not to be constructed within seismically active areas. New and existing facilities in a 100-year flood plain must be constructed to withstand flooding. **The regulations do not require consideration of other potential natural catastrophes, or of the protection of drinking water sources, wildlife habitat, or the presence of other sensitive environments.**

Exemption From Detection Monitoring Program

The regulations grant a waiver from detection monitoring requirements for land disposal designs using double liners with a leak-detection system between the liners. The exemption is made to encourage use of the state-of-the-art approach which EPA apparently assumes is effective in containing the waste and detecting any liquid migration. Little information is available, however, about the integrity and reliability of such systems over time. The primary liners of several facilities with similar design features have begun to leak early in the life of the facility.[169] Environmental groups argue that the waiver is not needed as an incentive to use state-of-the-art design, and that EPA could require all facilities to use that configuration. Moreover, **without a detection monitoring system in place, the effectiveness of the design cannot be determined, background water quality will not be established before contamination, and a post-closure monitoring system will not be in place to indicate leakage and trigger the corrective action requirement.** An additional complication with the provision is disagreement over what constitutes evidence of a leak in such facilities. The rules provide that the presence of any liquid between the liners is presumed to indicate leakage. If liquid is detected, the liner must be repaired promptly to maintain the ground water monitoring exemption. If such repairs are not made, the facility must immediately initiate a detection monitoring program (which may require a permit modification). Some industry representatives advocate a modification of EPA rules to specify that a leak exists when the detection system indicates the presence of "leachate" rather than "liquid," between the liners. These industry critics argue that the occurrence of liquid between liners is expected in the landfill operation and does not indicate a leak in the system. The use of leak-detection systems should provide earlier and more reliable warnings of potential migration of waste constituents. An important advantage is the greater ability to take corrective action, especially if the system is designed for pump-out control. The criteria used for determining failure will require careful evaluation, including leachate characteristics and site conditions.

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[169] Testimony of William Sanjour before the House Committee on Science and Technology, supra, note 168. Peter Montegue, "Four Secure Landfills in New Jersey—A Study in the State of the Art in Shallow Burial Waste Disposal Technology," (draft report) (Princeton, N.J.: Princeton University, 1981).

The exemption removes any opportunity for obtaining data on the reliable performance of these facilities. **Environmentalists and some industry critics have suggested that all facilities, regardless of the type of design, should be required to implement adequately designed detection monitoring programs. This would serve as a backup for the leak-detection system and could serve to verify that liquid does not migrate through such liners and result in environmental contamination.**

Exemption of Existing Portions.—Existing portions of land disposal facilities are not required to incorporate the same design specifications new facilities or units constructed after permit issuance, e.g., installation of single liners and leachate collection systems. EPA's decision to provide a limited exception is not based on the feasibility of installing such containment but on concern for the potential interruption of facility operation during the retrofitting process and on EPA's interpretation of the 1980 RCRA amendments providing for distinctions between new and existing facilities in setting performance standards. The "existing portions" exemption could have serious consequences for the protection of human health and the environment and on the development of safer treatment and disposal alternatives. The existing active portions of interim status land disposal facilities are not required to install liners and leachate collection systems. Moreover, the rules do not require surface impoundments to install leachate collection systems—a significant change from the January 1981 standards for surface storage impoundments.

The "existing portion" is defined as the "land surface area of an existing waste management unit described in the original Part A permit application on which wastes have been placed before the issuance of a final permit."[170] EPA has determined that each surface impoundment, or landfill cell or trench is a unit. Any lateral expansion from the "Part A" surface area is not considered an "existing" portion, but EPA does not limit the depth or height to which waste may be placed within this area before or after permit issuance. EPA estimates that it could take at least 5 years to review and permit all existing land disposal facilities.

During the period before permit issuance, existing interim status facilities can continue to construct and use additional new landfill and surface impoundment units without installing liners and leachate collection systems, even where such installation is clearly feasible without disrupting operations. The only apparent limit on construction and use of additional unlined units is that they may not go beyond the boundaries of the original Part A application and may not significantly increase the facility's design capacity without EPA approval. These units can continue to be used without retrofitting after the permit is issued. In contrast, a new facility which must have a permit for construction and operation would have to install liners and leachate collection systems at each of its units during the same period.

The continued use of these unlined existing facilities without any attempt at containment or retrofitting could result in situations endangering public health and the environment and require costly remedial action. Evidence of problems experienced with past waste disposal practices is well-documented (see table 81).

Table 81.—Contamination of Ground Water by Industrial Wastes

State	Number of incidents	Fraction attributed to: Industrial waste[a]	Landfill leachate[b]
Arizona	23	30%	26%
Connecticut	64	44	—
Florida	92	35	—
Illinois	58	21	28
New Jersey	379	40	—
South Carolina	89	31	—

[a] Presumably such contamination would be related to hazardous industrial waste, for the most part, rather than ordinary solid waste.

[b] Landfills could include both subtitle C and D types; but presumably the source of the contamination is hazardous waste.

SOURCE: V. I. Pye, "Groundwater Contamination in the United States," September 1982 (data based on numerous surveys which are documented).

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[170] 47 F.R. 32,349, July 26, 1982; to be codified at 40 CFR 260.10.

Existing units of land disposal facilities that receive waste after Jan. 26, 1983, will be subject to ground water protection monitoring and corrective action requirements (these are called "regulated units"). However, because of the limitations inherent in the detection monitoring program (similar to the interim status standards (ISS) monitoring requirements discussed later in this section), **contamination of ground water sources by existing facilities in many cases is not likely to be detected until pollution has reached serious proportions.** The outcome of EPA's decision on applicability of containment and ground water protection standards to existing facilities is likely to encourage the continued use of existing unlined land disposal units, with potentially increased contamination of ground water sources. An alternative would be to define "existing" portion as only those facility units or portions of facilities that were in use **before the effective date of the RCRA regulations—e.g., Jan. 26, 1983, or before Nov. 19, 1980.** Additionally, all existing facilities could be reviewed to identify those where retrofitting or installation of other containment technology is technically feasible.

Disposal of Liquids in Landfills

Although the first tier of land disposal strategy is to limit the amount of liquid in the facility that could form leachate or increase the hydraulic head, the rules allow disposal of bulk and containerized liquids if the facility has at least one liner and a leachate collection and removal system. In allowing this practice, EPA expressed the opinion that few existing landfills would qualify. The leachate collected must be removed from the landfill and treated. This treatment could mean placing the liquids back into the landfill, resulting in continuous recycling of the liquid. For certain wastes, this could result in **possible** decreases in the concentration of hazardous constituents. Critics emphasize that free liquids can migrate readily through a landfill, possibly dissolving harmful constituents that may be encountered in the migration path. **The adequacy and effectiveness of leachate collection and removal systems over long periods of time in landfills have not been demonstrated.** EPA rules provide that the collection system must operate over the life of the facility and at closure until leachate is no longer produced. This could be in excess of 30 years. Recycling liquids through the landfill could delay and complicate the eventual treatment of leachate or liquids. Furthermore, the continued presence of high volumes of liquids in a facility only serves to enhance potential damage to side walls and bottom liners.

Impact on Development of Other Technologies

Overall, the costs of complying with EPA's regulations of waste management appear to favor the continued use of land disposal techniques over other alternatives, such as incineration, or biological or chemical treatments. Many in the waste management industry expected that implementation of RCRA would make alternative treatment technologies more cost competitive and encourage the growth of an industrial segment devoted to the alternative treatment of hazardous wastes. This has not been the case:[171]

> To begin with, the construction of a high technology facility requires a large amount of capital. Furthermore, a great deal of that capital must be invested with the prospect of years of waiting before it can begin to generate a profit. Because of these two factors, disposal of toxic wastes by high technology . . . costs more than does unregulated landfilling. Therefore, there cannot be an economic return on the invested capital for such a facility so long as toxic waste which can be readily incinerated, treated, or stabilized is nonetheless directed to landfills because they are cheaper. Apparently it has been the perception of those who might have invested the capital that the EPA is unwilling to adopt a set of regulations which will result in high technology disposal being an economically viable alternative.

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[171] Statement of H. Clay Robinson for the Hazardous Waste Treatment Council in hearings on EPA's land disposal regulations before the Subcommittee on Natural Resources, Agricultural Research, and the Environment of the House Committee on Science and Technology, 97th Cong., 2d sess., Nov. 30, 1982, at p. 2.

Several factors support this conclusion: 1) Exemptions for existing portions of land disposal facilities allow them to escape more stringent design and performance standards required of new facilities and units; 2) There are insufficient restrictions on the type of wastes that can be placed in land disposal facilities; and 3) Differences in the quality and stringency of regulations for management technologies create an economic bias toward continued use of land disposal.

For example, as discussed in chapter 5, regulations for incinerators force this technology to perform much closer to its operational limits. Incinerators must achieve a destruction removal efficiency (DRE) of 99.99 percent or better. This is a difficult standard for some facilities to meet. In contrast, the land disposal regulations provide only limited incentives for the uses of more advanced landfill design (double liners with leak-detection systems and with external monitoring). EPA, in acknowledging that land disposal facilties eventually will release hazardous waste constituents to the environment, established the second-tier monitoring and remedial action strategy. By imposing stringent requirements for technologies which result in immediate, permanent destruction (e.g., incinerators) and less stringent requirements for other technologies, such as land disposal (which may require costly corrective action, where feasible) EPA is effectively promoting the use of the latter. At the same time, little attention is given to exploring incentives that would encourage the use of those technologies that reduce the hazard of industrial wastes.

Appropriate Use of Land Disposal Technology

It is widely acknowledged that there are appropriate circumstances for use of land disposal technologies for some hazardous wastes. For example, treatment technologies, such as incineration, produce residues that must ultimately be disposed. Landfills are appropriate facilities for containment of detoxified and immobilized waste provided that the facility is adequately designed and has an effective monitoring program. Biodegradable waste constituents can be deposited in the land if the facility can safely contain the wastes for the length of time required for degradation of the material. Treatment methods are available that can immobilize most, and reduce the toxicity of many, toxic metals before disposal.

Regulations for land disposal reflecting the most advanced state of treatment, containment, and monitoring technologies could promote the mandate of RCRA for protection of human health and the environment by: 1) reducing the risks associated with land disposal and 2) making the immediate costs of land disposal more comparable to other treatment options.

There are substantial long-term and indirect costs for containment options that the regulations do not address, such as the costs to future generations for increased health problems or the costs to provide remedial action at landfills in the future. The actual level of these costs and the extent to which they are incorporated into the operational expenditures of a facility will depend on: 1) Federal requirements for demonstrating financial responsibility for remedial actions and liabilities for damages, and 2) the extent of effective Federal enforcement. Current policies in these areas result in incomplete internalization of these costs, skewing the management options toward land disposal. However, not all generators have opted for the least costly alternative. Some assessed the potential long-term costs, liabilities, and uncertainties associated with land disposal options and have chosen treatment and waste reduction techniques. While many companies may wish to take this type of voluntary action, for a variety of reasons they are unable to do so—e.g., the size of the firm and of its competitive position may preclude the additional capital expenditures required.

Monitoring

Given the potential magnitude of environmental and health problems that could result through mismanagement of hazardous waste, adequate monitoring requirements for RCRA-permitted facilities are essential. Current EPA regulations require air emissions and process monitoring for incinerators, and ground water monitoring for land disposal facilities. **Although other environmental laws may impose additional monitoring requirements, these generally have not been applied to RCRA facilities.**

A general criticism of the RCRA regulations for hazardous waste management facilities is that the monitoring requirements may be insufficient to detect environmental contamination. Process and source monitoring has been specified, however, ambient monitoring is primarily limited to ground water monitoring at land disposal facilities. Although emissions of hazardous volatile organic compounds from surface impoundments and landfills has been documented as contributing to air pollution problems, monitoring to determine if these emissions pose a health hazard is currently not required under EPA regulations. The provisions for waivers and variances from various monitoring requirements also means that there may be no way to detect contamination during operation and after closure.

More expansive use of ambient monitoring holds the greatest potential for minimizing risks that might result from hazardous waste management. Ambient monitoring provides information on the appearance of statistically significant levels of contaminants in air, soil, water, and biota. By taking representative samples from potentially affected locations and environmental media and then analyzing them for a broad spectrum of potential contaminants it is possible to control risks reliably. If contamination of air, water, or land can be detected sufficiently early (before widespread contamination and actual damage) and corrective action taken, the human exposure will be reduced. **Ambient monitoring, therefore, should be given a greater role in the RCRA regulatory program.**

RCRA requires periodic operator inspections of equipment and structures at all hazardous waste facilities to assure that the facility is in compliance with applicable standards. The frequency of these inspections is based on the potential for deterioration or malfunction of particular equipment within each facility. EPA regulations establish specific inspection frequencies for different facilities and provide that more detailed inspection programs are to be set in the permit. Storage tanks, for example, must be inspected weekly to detect leaks and fugitive emissions. Inspection and monitoring records must be kept onsite for a period of 3 years.

Regulations for **treatment and storage facilities** primarily rely on visual inspections and process monitoring to detect malfunctions or possible releases into the environment. Monitoring requirements for **incineration** include process monitoring (feed-rate temperature, carbon monoxide, etc.) and the destruction removal efficiency rate for principal organic hazardous constituents in the waste feed and on emission rates of hydrogen chloride and particulates. Required monitoring of actual emissions from an incinerator is limited to trial burns conducted as part of the permitting process. As discussed in chapter 5, because of the criteria used to select principal organic hazardous constituents and the uncertainties about the adequacy of surrogate measures for DRE, this approach has been questioned.

Land Disposal

The monitoring requirements for landfills are severely limited in scope. With the exemption of land treatment facilities, primary emphasis is given to ground water monitoring, and that requirement can be waived under some circumstances. Testing of air, soils, vegetation, and other organisms for possible contamination is not required.

In general, the detection monitoring requirements at land disposal facilities may not serve as a reliable and effective early warning of environmental contamination. Significant contamination can occur before statistically significant changes in water quality can be detected. Some industry commenters have suggested that the EPA-suggested statistical method used to determine changes in ground water quality may tend to give a very high number of false positives (indicating contamination where none exists).

Under the compliance monitoring regulations, as with detection monitoring, severe contamination could occur before statistically significant differences are noted between background levels and ground water samples. According to EPA, analytical methodologies have been specified for all but 9 of 387 Appendix VIII constituents that during compliance monitoring must be tested for annually. However, the state of the art in chemical analysis makes it difficult to analyze for **all 387** hazardous waste constituents even if it is required only once a year. Moreover, facilities may petition to drop certain Appendix VIII constituents from required monitoring. Although testing for 387 Appendix VIII constituents may appear burdensome, these substances represent only a portion of the hazardous waste, and reaction products that could be present in ground water from a leaking land disposal facility.

Sampling is a critical and currently inexact step in any monitoring program. EPA ground water monitoring regulations for interim status and permitted facilities provide little guidance in designing monitoring programs for particular facilities. The minimum number and frequency of samples required may not be adequate for collection of meaningful data. The regulations place the burden on the facility operator for designing and the permit writer for approving an appropriate monitoring program and sampling schedule to provide "representative" measures of water quality and to detect possible contamination. More frequent sampling at more locations might provide better information on, and reduce uncertainties about, constituent behavior in landfills. Regardless of the statistical procedure used, differences between background and the monitoring signal using only a small number of samples would have to be very large (i.e., in some cases, order of magnitude changes) before statistically significant changes would be identified. Thus, ground water contamination could be substantial before statistical analysis verified that significant changes had occurred.

Seasonal variations also can influence constituent concentrations. Unless particular care is taken in the timing of a sampling effort, quarterly or semiannual sampling periods might not reflect these variations adequately, and thus misleading conclusions may be drawn.

Location and Number of Sampling Wells.—Proper location, depth, and installation of monitoring wells is critical to obtaining adequate and representative environmental samples of ground water to establish background levels and to measure any contamination. The number of monitoring wells is also critical because of the difficulty in predicting location of a plume before migration has occurred. EPA rules apply a general standard that the number and location of monitoring wells be sufficient to measure background levels unaffected by the facility and to immediately detect any migration of waste constituents from the facility. EPA has suggested that a minimum number might be one upgradient well and three downgradient wells. Given the uncertainties surrounding plume behavior and frequent lack of hydrological information, three monitoring wells may not be adequate. A 1977 EPA document recommended at least one downgradient well for every 250 ft of downgradient site border. However because of the complexity of many ground water systems there appear to be no universally acceptable rule of thumb that could be applied.[172]

Figure 24 illustrates a hypothetical problem related to well location. Because of the position of the plume, contamination of ground water is noted only in well B. The concentration of contaminants in a plume can vary sharply over short distances. If the plume at well B carries a low concentration, contamination would appear significantly lower than it is in fact. By the time contamination reaches well C, a good fraction of this aquifer already would be polluted. Typical corrective action initiated at this late stage in plume migration might not be adequate to restore the quality of

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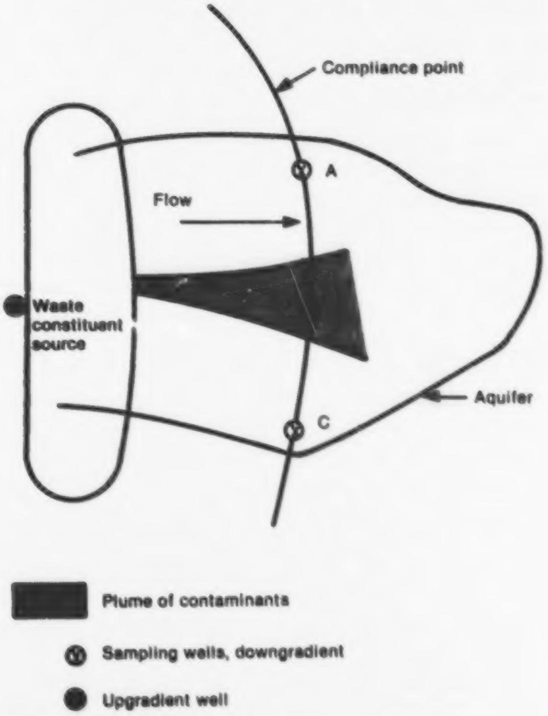
[172] U.S. EPA, *Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities*, EPA/530/SW-611, August 1977, p. 41.

Figure 24.—Sampling Well Locations for Ground Water Monitoring Program

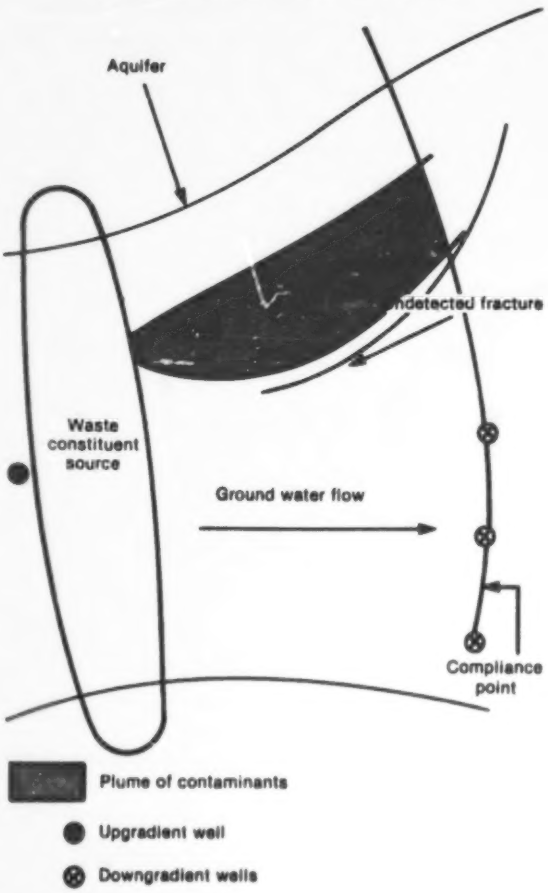

Compliance point
A
Flow
Waste constituent source
Aquifer
C
▨ Plume of contaminants
⊗ Sampling wells, downgradient
● Upgradient well

SOURCE: Office of Technology Assessment.

the aquifer or, if it is, it would be very expensive. Such a situation could be prevented if more wells were required, if they were more evenly placed, and if they were at different depths over the aquifer rather than only at the compliance point of a facility.

Furthermore, the movement of plumes of contaminants may be different than the direction of flow in the ground water. Concentrations of contaminants that are lighter or denser than ground water have been occasionally found to move in unpredictable patterns. Monitoring downgradient wells in such situations might not detect plume migration, and reliance on one upgradient and several downgradient wells may not provide the appropriate data. Figure 25 shows another hypothetical case in which undetected hydrologic features such as fractures or solution channels may influence ground water flow in unanticipated ways so that three downgradient wells could miss altogether the flow of contaminants from the source.

Figure 25.—Plume Migration May Not Flow With Ground Water Due to Gravitational Influence and/or Undetected Fractures in the Aquifer


Aquifer
ndetected fracture
Waste constituent source
Ground water flow
Compliance point
▨ Plume of contaminants
● Upgradient well
⊗ Downgradient wells

SOURCE: Office of Technology Assessment.

Testing Methodology and Establishing Acceptable Concentration Levels.— Decisions regarding the type and number of constituents that the detection and compliance programs are to monitor will be made by the permit writers in regional or State agencies.

If detection monitoring indicates possible contamination from a regulated unit at the compliance point, the operator must initiate a compliance monitoring program. This will generally require a modification of the permit to specify the ground water protection standard. (For existing facilities, where possible contamination is indicated during permit review, EPA will require immediate implementation of a compliance monitoring program as a condition of the initial permit.) The ground water protection standard consists of four elements:

1. the hazardous constituents to be monitored;
2. the concentration of each hazardous constituent that triggers the corrective action requirement (the compliance level);
3. the compliance point at which the level of contaminants is to be measured; and
4. the compliance period over which the ground water protection standard is applied.

In establishing the concentration limits for the contaminants, the Regional Administrator will use one of the following criteria:

- the background level of the constituent in the ground water; or
- the maximum concentration limits (MCL) for the 14 hazardous constituents which have been set under the Safe Drinking Water Act National Interim Primary Drinking Water Standards, if the background level is below the MCL; or
- an alternate concentration limit if the facility owner or operator can demonstrate that the constituent will not pose a present or potential hazard to human health or the environment as long as the alternate concentration limit is not exceeded.

During compliance monitoring, EPA will require testing for all of the 387 Appendix VIII toxic constituents at least annually. EPA has not established acceptable concentration levels for most of these hazardous constituents; therefore "background level" will be the predominant ground water protection standard used.

One concern is that the hazardous constituents selected for detection and compliance monitoring may not be representative of the range of substances leaching into ground water from the facility. An additional concern is that background levels may not provide adequate protection of public health and the environment in some areas, particularly if there is already some uncorrected contamination from past waste disposal practices at or near the facility. The land disposal regulations do not specify that wells establishing background water quality be located so as to avoid contamination by waste migration from nonregulated waste management units in the waste management area.[173]

The second standard of pollution up to the established MCLs for drinking water gives the facility an additional margin of permissible pollution before corrective action is required in cases where contamination exceeds background levels. The maximum contaminant limits were adopted in 1975 based largely on the 1962 Public Health Service Drinking Water Standards, including standards for bacteria, turbidity, 10 inorganic ions, and 6 persistent pesticides. These standards originally were intended to set minimum requirements for drinking water quality in public waste systems and not as measures of acceptable environmental contamination for ground water.

Approval of an alternate concentration limit could allow contamination in excess of background or of the MCLs in individual cases. The burden of establishing an alternate concentration limit is on the facility operator. The alternate concentration limit or "narrative criteria" is probably the most controversial of the protection standards because it is set largely on a site-specific basis. The regulations specify factors for the Regional Administrator to consider in deciding whether to approve an alternate concentration limit for compliance monitoring at a facility where possible ground water contamination has been indicated. In deciding if the constituent will not pose a substantial present or potential hazard to human health or the environment, the Administrator will consider such factors as potential adverse effects on surface and ground water quality; the characteristics of the waste; its potential for migration; hydrological characteristics of the facility and surrounding area; the rate and direction of ground water flow; distance to current and future ground water users; other sources of contamination; potential damage to the environment; and the persistence and permanence of any effects of exposure.

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[173] See 47 F.R. 32,352; to be codified at 40 CFR 264.97(a)(1).

Critics of the alternate concentration limit argue that establishment of acceptable levels of contamination on a case-by-case basis raises significant public policy issues related to potential exposure to carcinogenic, mutagenic, embryotoxic, teratogenic, or otherwise toxic substances that should not be left to the discretion of the Regional Administrator or State permit writer, but rather should be resolved on a uniform national basis.

Hazard/Risk Classification

In the initial development of regulations for implementing the RCRA mandate, EPA chose not to use a waste hazard classification system because:[174]

1. EPA considered that none of the proposed systems was adequate for distinguishing differences among industrial wastes; and
2. the Agency considered that the regulations achieved the objectives of a hazard classification system.

EPA stated its intention that waste management regulations would eventually be tailored to reflect differences in potential hazards of wastes, as well as differences in environmental conditions surrounding the facility site. Current regulations for waste identification and facility permits include provisions that involve some evaluation of the degree of hazard or risk posed by the waste, but only in the most qualitative and site-specific ways.

At certain points in the process of listing and delisting hazardous wastes, assessments of hazard levels are possible, but EPA's decisions are not based on any comprehensive degree-of-hazard system based on scientific criteria open to external review. The generic lists of hazardous wastes include those materials which are considered by EPA to be the most hazardous, and for which the most information concerning health and environmental impact was available. In deciding to list a waste, EPA can consider such factors as toxicity, mobility, persistence, and possibilities of mismanagement.

EPA does distinguish between different hazardous wastes in the RCRA regulations by designating some listed wastes as "acute hazardous wastes"[175] or "toxic wastes."[176] Under EPA's small generator exemption, generally available to firms that generate or accumulate waste in amounts less than 1,000 kg/month, the exemption level for wastes that are designated as either acutely hazardous or toxic is reduced to 1 kg/month. There does not appear to be a sound technical basis for deciding which wastes are acutely hazardous or toxic wastes.

EPA regulations authorize waivers of some facility standards for certain types of hazardous waste. For example, EPA exempts incinerators that burn waste deemed hazardous solely because it is ignitable, corrosive, or reactive from some of the interim status incinerator standards and from some of the permit standards, if the operator demonstrates that the waste would not reasonably contain any Appendix VIII toxic constituents. EPA adopted the exemption because such wastes do not pose the hazards that the interim status and final technical facility standards for incinerators are intended to control.[177]

Current regulations suggest areas where formal risk-assessment methodologies might be used to assist decisionmakers, such as in establishing individual facility permitting conditions, in granting variances or waivers from ground water monitoring requirements, or in granting variances in liability insurance coverage.

EPA considered the use of quantitative risk assessment as part of its hazardous waste regulatory scheme in the February 1981, **proposed** land disposal regulations "environmental performance standards."[178]

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[174] 45 F.R. 33,164, May 19, 1980.

[175] 40 CFR 261.33(e) (1982).

[176] 40 CFR 261.33(f) (1982).

[177] See the Jan. 23, 1981, Phase II incinerator standards preamble, 46 F.R. 7666.

[178] 46 F.R. 7666.

Industry critics, who had earlier advocated the use of more flexible performance standards rather than design standards, characterized the proposed EPA risk-assessment approach as "potentially nightmarish in application." To conduct the risk assessment, applicants would have to supply detailed hydrological studies and submit health effects data. EPA informally estimated that such backup studies might cost as much as $1 million per facility. In May 1981, EPA published a notice that it was encountering "profound conceptual difficulties" in the proposed risk-assessment approach and sought further comment. The July 1982 land disposal regulations did not require the use of formal quantitative risk assessments in permitting facilities or in granting variances.

EPA's January 1981 **proposed** variance procedure for permitted incinerators also would have incorporated the use of quantitative risk assessment on a case-specific basis. In permitting incinerators, it would have allowed a more detailed consideration of factors related to protection of human health and the environment not addressed in the 99.99 percent DRE performance standard (e.g., the absence of any limit on the actual mass of hazardous constituents emitted), site- and waste-specific factors, toxicity, incinerator design, location, climate, and population distribution. EPA observed that use of risk analysis could provide flexibility in determining the necessary level of protection.

In publishing its revised incinerator standard in June 1982, EPA deferred action on the proposed use of risk assessment but did not rule out its eventual application.[179] EPA noted that a risk analysis of the type proposed requires extensive data, which are rarely available and which therefore must be collected either directly or simulated by computer model. The accuracy and precision of the data and models used must then be analyzed before meaningful risk analysis can be conducted. A primary goal of EPA's ongoing regulatory impact analysis (RIA) is to characterize the risks to human health and the environment associated with the incineration of hazardous waste. According to EPA, "the RIA will provide valuable information regarding the **feasibility** of conducting site-specific risk assessments, therefore any action on the January 1981 proposal for use of risk assessment to be used in setting variances from the performance standard would be premature."[180] EPA's risk-cost policy model discussed in the appendix to this chapter is the principal assessment model being used in its regulatory impact analysis.

Certain solid and hazardous wastes are excluded or exempted from RCRA regulation by statute and by rule. These exceptions frequently have been made without any assessment of the inherent hazard of the wastes or the potential effects on human health or the environment from improper handling of these wastes. In contrast, listed waste and mixtures of listed wastes must be managed as hazardous waste without respect to the concentrations of such hazardous constituents or their degree of hazard until and unless they are delisted. Critics argue that this ad hoc system of exemptions and exclusions allows certain potentially hazardous waste to escape proper management or oversight. Exempted or excluded materials, regardless of the reason for, or the status of, the exemption, can be buried in subtitle D landfills which may not adequately contain these wastes. Because of the design of these facilities, hazardous constituents potentially could be released into the environment.

One of the most controversial exemptions is the **small quantity exemption**. Wastes from small generators are not tracked through the manifest system and can be treated or disposed of either in permitted hazardous waste facilities or in subtitle D sanitary landfills. EPA included this initial exemption in its regulatory program because of the administrative problems in overseeing thousands of small generators, such as drycleaners, gas stations, and paint stores. The exemption was based on administrative convenience and not on the hazard posed by the waste and its unregulated disposal.

A report by the Subcommittee on Oversight and Investigations of the House Committee on

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[179] 47 F.R. 27,518, June 24, 1982.

[180] Id.

Interstate and Foreign Commerce concluded that:

> . . . small generators who produce especially dangerous hazardous waste will not be adequately regulated. The amount of waste produced should not be the only criterion considered. The degree of hazard posed by the waste generated is, in the Subcommittee's opinion, much more important.[181]

Some supporters of the small quantity exemption argue that a high rate of dilution will assumedly take place when a limited amount of hazardous material is disposed with large amounts of nonhazardous substances. However, there is little evidence to support this assumption. Sanitary or municipal landfills in industrial regions will frequently receive small quantities of hazardous wastes from several sources so that the overall load of hazardous waste in these landfills, which were not designed to contain them, could be substantial. If the waste is primarily low-hazard material that is rapidly degraded, there may not be a serious problem. If, however, the material is highly toxic, the consequences could be severe. The proposed National Priority List contains many solid waste landfills that received hazardous waste from firms that probably would be considered small generators under current rules. Past disposal practices at these sites pose substantial threats today to human health and the environment. Under a small generator exemption that focuses on the quantity of the waste and not the degree of hazard that it poses, these inadequate disposal practices will continue.

Risk Management

The use of various methods for quantitative evaluations of risk is receiving increasing attention in the Federal hazardous waste programs under RCRA and the Comprehensive Environmental, Response, Compensation, and Liability Act (CERCLA). Examples of different risk estimation approaches include:

1. estimations of the risk associated with operation of particular management facilities, used in granting waivers or variances to RCRA regulations;
2. risk/cost models to be used in policy and regulatory development for RCRA; and
3. use of the hazard ranking system in identifying priority sites for Superfund cleanup.

Risk Estimation

In deciding whether a facility qualifies for a waiver or variance of certain RCRA regulations, the rules specify that the potential for harm to human health and the environment must be considered. For example, land disposal facilities can be exempted from ground water monitoring programs if it is shown that there is low potential for migration of the waste from the facility to drinking water sources. Such risk estimates are generally of a qualitative and judgmental nature and do not follow any specified or formalized quantitative methodology. As discussed above, EPA has considered incorporating the use of quantitative risk-assessment techniques in the permitting of hazardous waste land disposal facilities and incinerators. The tools available for performing risk assessment are not yet at final stages of development; therefore, results generated must be interpreted cautiously if they are to be incorporated into the decisionmaking process. The difficulties of using risk-assessment tools are generated primarily by limitations on the assumptions used in these models. Generalizations may be inaccurate for specific sites, inadequate data bases may be used, criteria for assessing hazard and risks are lacking, and long-range performance cannot be predicted using currently available data.

A recent study prepared by Engineering Science for the Chemical Manufacturers Association attempted to estimate risks associated with incinerators and landfills.[182] Certain generic problems were emphasized:

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[181] Subcommittee on Oversight and Investigations, Committee on Interstate and Foreign Commerce, *Hazardous Waste Disposal* (Committee Print), 96th Cong., 1st sess (1979).

[182] Engineering Science, *Comparative Evaluation of Incinerators and Landfills for Hazardous Waste Management*, report for the Chemical Manufacturers Association, Washington, D.C., 1982).

1. **Because of the many assumptions required in determining most estimates, the result is at best an approximation of the actual risk.** This may be particularly true when calculations are required prior to actual operation of a facility. In this situation, data are limited, and assumptions about performance efficiency will skew the results. The difficulties and uncertainties in predicting the environmental fate of constituents (as discussed in ch. 6) also contribute to this problem.

2. **Currently available data bases are inadequate for reliably estimating risks.** Data relating to health effects from exposures are incomplete and are not standardized with respect to test organisms, protocols used, and routes of exposure. Also, published information may not be conclusive. For example, one compound may be considered carcinogenic in one study, but noncarcinogenic in another; it may produce adverse effects in mice, but not in rats. In addition, it should be emphasized that the absence of evidence in any test situation does not equal evidence of no effect. Because of such problems, **predictions** of the potential risk to human health resulting from future use of a waste management facility will be very uncertain.

3. **Criteria for acceptable risk or standards for acceptable environmental concentrations of constituents do not exist for most hazardous waste constituents.** Without such criteria or standards, judgments about acceptable levels of risks resulting from operation of a facility would be arbitrary.

4. **The methodologies used do not consider changes in risk over time for either facility operation or the environmental fate of constituents.** For example, if emissions from a facility are marginally acceptable, current models do not permit consideration of a decrease in efficiency over time that could lead to potential accumulation and environmental buildup of constituents, as well as low-probability accidental releases that may be larger than steady-state release values.

A major omission in EPA's various proposals for implementation of risk estimation is development of criteria on which to judge whether such risk estimates represent an acceptable level of risk to human health and the environment. A permit writer or Regional Administrator must decide: 1) whether the estimation methodology is appropriate, 2) whether the quality of data is adequate, and 3) acceptable risk levels. Decisions on all of these will be difficult if agency permit writers do not have either training or sufficiently detailed interpretive guidance documents.

Hazard Ranking System for CERCLA

In order to set priorities for remedial action at uncontrolled hazardous waste sites, CERCLA requires that EPA establish specific ranking criteria based on: relative risk or danger, population at risk, hazardous potential of a substance or substances at a site, potential for drinking water contamination, potential for direct human contact, and the possibility of destruction of sensitive ecosystems. To meet this mandate, EPA developed the Hazard Ranking System (HRS).[188] (It is also referred to as "the Mitre Model" because it was initially developed by that group for EPA.) The HRS is a tool for applying uniform technical judgment regarding the potential hazards presented by a facility relative to other facilities. EPA's description of this system is presented in the appendix to this chapter.

An OTA review of the HRS identified certain problem areas in the methodology for assigning a hazard score for any site which could result in a ranking that does not adequately reflect the risk posed by releases at the site.

1. The score for hazard potential is based on only the most hazardous substance in the site rather than a composite of all constituents. In contrast, **all** substances are used to quantify the magnitude of this hazard. For example, one site may contain predominantly low-hazard wastes (e.g., 100 tons) with small quantities of a highly hazardous substance (e.g., only 8 tons). Another site might have the same amount (8 tons) of an equally high-hazardous substance, but no other

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[188] 47 F.R. 31,210-31,243, July 13, 1982 to be codified at 40 CFR Part 300.

material. This latter site, in comparison with the first, would receive a lower score based only on volume, although the hazard is equal.

2. **Low-population areas will tend to receive a lower score than high-population areas using the HRS, making it less likely that CERCLA funds for remedial action would be allocated to sites in these mostly rural areas, without regard to the relative number of persons actually exposed and the nature of the hazard.** One major component of the HRS is based on the size of the population served. If 100 or fewer persons are being served by a threatened water source, the score would be less than if a larger number of people were involved. While it is reasonable to expect that those sites near urban centers may present a threat to large numbers of people, this is not always the case. For example, if the dilution potential were large (i.e., constituents from the site migrate toward a large river), the actual exposure dose to the population may be quite small. The number of people served by a potential water source is only an **indicator** of the population at risk; it should be emphasized that the number of people actually **exposed** to hazardous constituents may not be proportional to the population **served.** If the HRS is used to determine allocation of funds to priority sites, then CERCLA funds will be used only when large numbers of people **may be** exposed, and may not be allocated when relatively few people are **actually** exposed, without regard for the degree of hazard posed by a site.

3. Another component of the score is based on distance to some specified point of exposure. For ground water, it is the distance to the nearest well drawing water from an aquifer; for surface water, it represents the distance to the closest water intakes; and for air, it is the distance to the nearest sensitive environments. Prior to a release from a site, these are reasonable factors to be used. The greatest hazard is presumed to be located nearest the site in question. Following a release from a site, however, distance to an exposure point has only marginal significance for the degree of hazard posed. Because of the mobility characteristics of contaminant plumes within ground water aquifers, it is possible that a well located 3 miles from a site could have higher concentrations of hazardous constituents than a well located only 2,000 ft from it. The important factor after constituents have been released to the environment is whether direct evidence of contamination exists at any exposure point.

In addition to these three specific problems, a more general criticism of the HRS is that no provisions exist for incorporating additional technical information about a site. The HRS has merit as a tool for processing substantial amounts of information on many sites. Certain types of technical information, however, that can be helpful for assessing relative degrees of hazard are not used. Such information would include:

1. amounts and kinds of observed releases (e.g., whether a release involves the most hazardous substances at a site);
2. possible attenuation of the released constituents along a route of transport;
3. particularly sensitive populations receiving known doses;
4. transient populations that may receive acute exposures; and
5. populations at risk, which are located at distances greater than the 3-mile limit imposed by the HRS.

At issue is the extent to which the current procedure may lead to inaccurate conclusions about the hazards posed by any site. **It is conceivable that a truly hazardous site may not score sufficiently high to receive attention and that a site, which may pose a relatively lower threat, could receive a score that suggests high hazard.** It should be possible to develop methodology so that HRS scores reflect actual hazard. For example, problems associated with both waste quantity and population can be resolved by assigning a maximum score for both of these factors whenever the toxicity-persistence score is above a certain level. The criticism concerning distance to exposure point could be addressed either by adding another factor to the scoring system that indicated direct evidence of contamination at exposure points, or by replacing the distance factor with one more relevant to direct exposure regardless of distance. A mechanism that incorporates additional data would have the added benefit of providing an incentive for States and industry to obtain more detailed information about particular sites.

Risk/Cost Policy Model

In response to a request by the Office of Management and Budget to conduct a regulatory impact analysis under President Reagan's Executive Order 12291, including consideration of using degree of hazard as a basis for RCRA regulation, EPA has developed a risk/cost policy model. The model consists of a multidimensional framework that organizes and combines various characteristics of waste (W), environmental settings (E), and management technologies (T). Scores for cost and risk are assigned to each W-E-T combination. The costs are defined as representing real resource costs such as capital and operating expenditures; risks are defined as risk to human health only and are based on toxicity and exposure measures. **There is no consideration of environmental hazard.** Details regarding the model and the OTA critique are presented in the appendix to this chapter.

The data base compiled for the model currently includes 83 industrial wastes. Information on these wastes includes physical characterizations, toxicity data for hazardous constituents, concentrations of waste constituents, an estimate of the total amount of generated waste by type, a mean value expressed as kg/day/generator, and potential treatment technologies. A broad range of technology choices has been provided. Any W-E-T combination can include one to three treatment technologies, one transportation option, and one land disposal option. Typical routine release rates representing some level of risk are included in the data base, as are costs for each treatment and disposal technology. Three indicators of human health risk have been identified: assimilative capacity of surface water located near a site, contamination potential of nearby ground water sources, and population density near a site. Each is represented by different levels—high, medium, or low.

Any model that will be used to develop policy and set priorities for regulatory reform should describe realistic conditions as closely as possible. The risk/cost policy model incorporates inadequate data management practices and unrealistic measures of human health risks; thus, the results could lead to policies and regulatory changes that have detrimental rather than beneficial impact on a national waste management approach.

The data base includes some wastes that currently are considered nonhazardous and are regulated under Subtitle D of RCRA (solid, nonhazardous wastes). EPA is attempting to establish subtitle C policies and regulations using a data base that is a mix of hazardous and nonhazardous substances. The technologies considered as major **single** treatments for the wastes in this model are incineration and chemical fixation/stabilization. Available information concerning waste management options suggests that these are not the major alternatives currently used.

The measures used to assess risk for various environmental conditions are so simplistic as to yield inaccurate estimates:

1. Flow rate of surface water is the **only** measure used to assess assimilative capacity. The potential for assimilation in any water system actually depends on a variety of factors, of which flow rate is only one.
2. The only measure used to represent the contamination potential of ground water sources is soil permeability. This oversimplifies the influence different factors have on ground water contamination and does not accurately represent the potential migration through soil or movement of a plume of constituents through ground water.
3. Population density near a facility is assumed to represent the population at risk. This is inaccurate, as identification of a population or individuals at risk depends on several exposure factors and individual

sensitivities to the constituents involved, more than the numbers of people residing near a facility.

Modifications made to risk scores give disproportionate and unjustified weight to dilution capability and size of the nearby population without considering the actual environmental fate of the constituents. As the model is formulated, a persistent compound released into an environment with a low-population density could receive a lower risk score than a biodegradable constituent released at a location with a high-population density; thus, the actual risk posed by a waste may be misrepresented through the use of this methodology.

Regardless of which waste or technology is incorporated within a W-E-T combination, the risk scores decrease with decreasing population density. Because of the way costs have been identified for the various treatment options, there is a bias in favor of land disposal. **Thus, results of this model will represent land disposal located in areas of low-population density as having the most favorable costs and risks when compared with other waste management alternatives and population densities.**

Appendix 7A.—Hazard Ranking System

As part of the National Contingency Plan, EPA developed a Hazard Ranking System (HRS) to be used to prioritize those uncontrolled sites that might require CERCLA funds for remedial action. The HRS methodology is applied by EPA and the States using data from observed or potential releases to obtain a score representing an estimate of the risk presented by each release. The score for each release is then used with other considerations in determining its placement on the National Priority List.This system is summarized by EPA as follows:[1]

> The HRS assigns three scores to a hazardous facility:
>
> - S_M reflects the potential for harm to humans or the environment from migration of a hazardous substance away from the facility by routes involving ground water, surface water, or air. It is a composite of separate scores for each of the three routes.
> - S_{FE} reflects the potential for harm from substances that can explode or cause fires.
> - S_{DC} reflects the potential for harm from direct contact with hazardous substances at the facility (i.e., no migration need be involved).
>
> The score for each hazard mode (migration, fire and explosion and direct contact) or route is obtained by considering a set of factors that characterize the potential of the facility to cause harm . . . Each factor is assigned a numerical value (on a scale of 0 to 3, 5, or 8) according to prescribed guidelines. This value is then multiplied by a weighting factor yielding the factor score. The factor scores are then combined; scores within a factor category are added; then the total scores for each factor category are multiplied together to develop a score for ground water, surface water, air, fire and explosion, and direct contact . . .

The HRS does not quantify the probability of harm from a facility or the magnitude of the harm that could result, although the factors have been selected in order to approximate both those elements of risk. It is a procedure for ranking facilities in terms of the potential threat they pose by describing:

- the manner in which the hazardous substances are contained,
- the characteristics and amount of the harmful substances, and
- the likely targets.

Table 7A.1 shows the factors used and the information required in applying the HRS.

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[1] National Oil and Hazardous Substances Contingency Plan, 47 F.R. 31,180, July 16, 1982..

Table 7A.1.—Comprehensive List to Rating Factors

Hazard mode/ factor category	Factors		
	Ground water route	Surface water route	Air route
Migration			
Route characteristics	• Depth to aquifer of concern • Net precipitation • Permeability of unsaturated zone • Physical state	• Facility slope and intervening terrain • One-year 24-hour rainfall • Distance to nearest surface water • Physical state	
Containment	• Containment	• Containment	
Waste characteristics	• Toxicity/persistence • Hazardous waste quantity	• Toxicity/persistence • Hazardous waste quantity	• Reactivity/incompatibility • Toxicity • Hazardous waste quantity
Targets	• Ground water use • Distance to nearest well/population served	• Surface water use • Distance to sensitive environment • Population served/distance to water intake downstream	• Land use • Population within 4-mile radius • Distance to sensitive environment
Fire and explosion			
Containment	• Containment		
Waste characteristics	• Direct evidence • Ignitability • Reactivity • Incompatibility • Hazardous waste quantity		
Targets	• Distance to nearest population • Distance to nearest building • Distance to nearest sensitive environment • Land use • Population within 2-mile radius • Number of buildings within 2-mile radius		
Direct contact			
Observed incident	• Observed incident		
Accessibility	• Accessibility of hazardous substances		
Containment	• Containment		
Toxicity	• Toxicity		
Targets	• Population within 1-mile radius • Distance to critical habitat		

SOURCE: 47 F. R. 31, 221, July 16, 1983.

Appendix 7B.—Risk/Cost Policy Model

In response to a request by the Office of Management and Budget to consider degree of hazard as a basis for regulation, EPA has developed a risk/cost policy model. This model was developed by three consulting firms and presented in a report, *Risk/Cost Policy Model Project, Phase 2 Report.*[4] The abstract of the report states:

> The RCRA Risk/Cost Policy Model establishes a system that allows users to investigate how tradeoffs of costs and risks can be made among wastes, environments, and technologies (W-E-T) in order to arrive at feasible regulatory alternatives.

There are many components in the system. Eighty-three hazardous waste streams are ranked on the basis of the inherent hazard of the constituents they typically contain. The system assesses these waste streams in terms of the likelihood and severity of human exposure to their hazardous constituents and models their behavior in three media—air, surface water, and ground water. The system also incorporates the mechanisms by which the constituents are affected by the environment, such as hydrolysis, biodegradation, and adsorption.

A second integral part of the system is the definition of environments in which the hazard components are released. Thirteen environments including a special category for deep ocean waters are defined on the basis of population density, hydrology, and hydrogeology. The system adjusts the exposure scores of the waste streams' hazardous constituents to account for their varying effects in the three media in each of the environments.

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[4] ICF, Inc., *RCRA Risk/Cost Policy Model Project, Phase 2 Report,* submitted to EPA, Office Solid Waste, Washington, D.C., 1982.

The third component of the system consists of the technologies commonly used to transport, treat, and dispose of the hazardous waste streams. This includes 3 types of transportation, 21 treatment technologies, and 9 disposal technologies. The system determines cost and release rates for each of these technologies based on the model's existing data base. It also incorporates estimates of capacities of the technologies, the amount of waste to be disposed of, and the proximity of the wastes to the available waste management facilities.

The model contains a multidimensional framework that combines various characteristics of waste (W), environmental settings (E), and management technologies (T), which includes treatment, disposal, and transportation technologies. Each combination of W-E-T includes one waste, one environmental setting, up to three treatment technologies, one disposal technology, and one transportation technology. Scores (based on logarithmic scales) are assigned to each W-E-T for cost and risk. Costs are defined so as to represent real resource costs such as capital and operating expenditures; the latter include labor, utilities, maintenance, and transportation. Risks are defined as risk to human health only and are based on toxicity and exposure methods; no consideration is given to environmental hazards.

The data base compiled for the model currently includes 83 industrial wastes. Information has been gathered regarding physical characteristics of the wastes, toxicity data on hazardous constituents, concentrations of these constituents, an estimate of the national amount generated for each, and an average value that represents kg/day/generator.

Table 7B.1 illustrates the technologies included in the data base; a broad range has been considered. Specific treatment options have been identified for each waste based on engineering judgments of the consulting firms. For each waste, several technology choices have been identified. For example, a particular waste might have the following treatment choices listed in the data base:

1. chemical coagulation as a single treatment;
2. vacuum filter and evaporation/drying in combination;
3. incineration as a single treatment (assuming pretreatment);
4. chemical fixation/stabilization as a single treatment; and
5. chemical precipitation and incineration in combination.

Table 7B.1.—Treatment, Transportation, and Disposal Technologies for the EPA Risk/Cost Policy Model

Treatment	Transportation	Disposal
Phase separation		
Chemical coagulation	Onsite	Double-lined landfill,
Filter press	Local	Single-lined landfill,
Centrifuge	Long distance	Unlined landfill,
Vacuum filter		Double-lined surface impoundment
Component separation		
Evaporation/drying		Single-lined surface impoundment
Air stripping		
Steam stripping		Unlined surface impoundment
Solvent extraction		
Leaching		Land treatment
Distillation		Deep-well injection
Reverse osmosis		Ocean
Carbon adsorption (PAC)		
Ion exchange		
Chemical transformation		
Chemical precipitation		
Chemical destruction		
Electrolytic decomposition		
Chemical fixation/stabilization		
Incineration		
99.99% DRE		
99.90% DRE		
99.00% DRE		
90.00% DRE		

SOURCE: ICF, Inc., 1982.

The technology element of each W-E-T combination includes a choice of one to three treatment technologies, one transportation option, and one land disposal option. Thus, a W-E-T combination for the above example would include one of the single or combined treatments, one of three transportation options, and one of nine disposal options. For all technologies, typical routine release rates representing some level of risk are included in the data base. Costs associated with each treatment and disposal technology also are provided.

The model identifies three environmental indicators of human health risk: assimilative capacity of surface water located near a site, contamination potential of nearby ground water sources, and population density near a site. Each indicator is represented by different levels—i.e., high, medium, or low. All possible combinations of these indicators representing 12 environmental settings are illustrated in table 7B.2. Deep ocean waters constitute a separate environmental setting.

Two different levels are used to represent assimilative capacity for surface waters. Low assimilation represents a high-risk situation and is identified by the following conditions:

1. low-flow streams;

Table 7B.2.—Environmental Settings Used in the EPA Risk/Cost Policy Model

Popultion density	Assimilation	Contamination
1. High (<520 people/km^2)	Low (<3 × 10^8 m^3/day)	High (0.2 km/yr)
2. High	Low	Low (20 km/yr)
3. High	High (<3 × 10^8 m^3/day)	High
4. High	High	Low
5. Medium (<52 people/km^2)	Low	High
6. Medium	Low	Low
7. Medium	High	High
8. Medium	High	Low
9. Low (<52 people/km^2)	Low	High
10. Low	Low	Low
11. Low	High	High
12. Low	High	Low
13. Deep ocean waters		

SOURCE: ICF, Inc., 1982.

2. large streams where drinking-water intakes are located downstream and within 6 hours of the waste facility at an average flow rate; and
3. areas subject to frequent flooding—e.g., a 100-year flood plain.

High-assimilative capacity represents high rates of flow or high-volume surface waters—i.e., large streams, estuaries, or lakes. This category is considered a low-risk situation in the model.

Criteria for determining low-risk levels for contamination potential of ground water include:

- locations above aquifers already contaminated to 100 times current drinking water standards;
- soil permeability of less than 10^{-6} cm/sec and depth to ground water saturation greater than 10 m; and
- soil permeability less than 10^{-4} cm/sec and depth to ground water saturation greater than 100 m.

High-risk levels for ground water contamination include all other conditions and those locations with major earthquake threats.

Population density near a waste management facility is used to indicate the population at risk. High-population density is defined as that with greater than 520 people/km^2, medium density as 52 to 520 people/km^2, and low density as any area with less than 52 people/km^2.

Limitations in Use of the Model

As is evident by the following exerpts from the *Risk/Cost Policy Model Project, Phase 2 Report*, those most directly involved with development of the model have a clear grasp as to its limitations. EPA staff working on the model appear to understand that it is in at early stage of development, that there are considerable uncertainties associated with results, and that a need exists to spend more time in development and validation of the model.

> EPA's purpose in developing the RCRA Risk/Cost Policy Model is to assist policymakers in identifying cost-effective options that minimize risks to health and the environment. The framework of the system is intended as a screen—to identify situations that are of special concern because of the risks they pose and to determine where additional controls may not be warranted in light of the high costs involved. The framework uses a data base that is too imprecise and general to be the sole basis for regulations. The results of the model will be used in more detailed Regulatory Impact Analysis to determine whether some type of regulatory action is warranted.[3]
>
> * * *
>
> . . . results of the model will be used at a high level of generality (to set priorities rather than to design specific regulations) . . .[4]
>
> * * *
>
> Most important, **this model cannot be used to evaluate particular permit applications.**[5]
>
> * * *
>
> This degree of imprecision means that the results cannot be used in a specific regulation-making context. We could, of course, use our general methodological approach to reach specific conclusions, but to do would involve substantial effort and time, which should probably be spent only on a very small number of regulatory options of the highest priority. Even if we used the tool in such a limited fashion, we would have to make substantial changes in the present assumptions. Because of the level of generality at which we operated, it would be **improper to apply the risk and cost values to a specific situation.**[6]

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[3] ICF, op. cit., abstract.
[4] Ibid., p. 1.6.
[5] Ibid., p. 1.8.
[6] Ibid., p. 1.10.

* * *

> Although a number of assumptions hamper specific analysis, we believe that the tool is highly useful at the general level of application for which it is intended.[7]

* * *

> The risk/cost policy model provides a framework for debate over alternatives, but requires restraint in applications and interpretation. The major assumptions and simplifications render detailed insight into the specifics of a regulation impossible.[8]

Statements made by the Administrator of EPA before congressional committees, however, suggests that the Agency intends to use this model for regulatory reform and rulemaking. In the land disposal regulations and in several statements presented at congressional hearings (as illustrated below) during the past year by senior officials, EPA has indicated that it will use the model quite soon. It must be emphasized that while these statements do not specifically refer to the Risk/Cost Policy model, it has been referred to as the Agency's degree-of-hazard approach.[9]

> Reexamination of existing regulations—in light of the extensive comments received on Phase I and Phase II regulations, we are undertaking a major reexamination, including: . . . An analysis of the cost/risk/feasibility factors in managing various types of waste to enable use to tailor standards for the control of specific classes of hazardous waste; . . .[10]

* * *

> Even as we near completion of RCRA's regulatory framework, we continue our pursuit of the Administrator's goals in the area of regulatory reform. To this end, all our regulations are now undergoing a degree-of-hazard analysis to determine whether the requirements need strengthening or whether they are already too stringent.[11]

* * *

> Tailoring of standards for specific wastes—apart from the specific regulatory activities discussed immediately above, EPA is conducting regulatory impact analyses for each of the various types of waste management units. In addition, it is conducting a degree-of-hazard study which will examine various combinations of waste types and volumes, treatment and disposal technologies, and environmental settings. This study is intended to identify ways in which RCRA Subtitle C standards could be tailored to better address particular problems. Based upon these studies, EPA hopes to propose appropriate regulatory amendments in 1983 and promulgate them in 1984.[12]

OTA believes that it will be some time before the model offers results of sufficient certainty to have confidence in its use for policy development or regulatory reform. At some time in the future, after results are verified, it would be appropriate to use it as a "screening" tool, to determine Agency priorities and areas for regulatory reform, and to "tailor" or "fine tune" RCRA regulations. In conjunction with other work, the model might be used to determine which wastes might be prohibited from landfills, what wastes would qualify for exemption from small quantity generators, and what facilities might qualify for regulatory exceptions and variances, or for class permits.

OTA Critique of the Risk/Cost Policy Model

Preparing a critique of this model from the Phase 2 Report was exceedingly difficult. Important information about actual application was missing, and many errors were noted. The report was poorly written—therefore, several interpretations for appropriate use of the methodology were possible. Only after a 6-hour meeting with the contractors and EPA representatives did OTA feel that sufficient information was in hand to attempt this critique. **This fact must be emphasized.** If persons trained in the various disciplines that are incorporated in the model have difficulty interpreting both methodology and results, it seems unlikely that administrative officials will be able to apply the model correctly.

Even when a model is to be used **only** as a screening tool for developing policy and setting priorities for regulatory reform, it is important that its elements describe real conditions as closely as possible. Because the Risk/Cost Policy Model incorporates inadequate data about management practices and unrealistic assumptions, reliance on its results could lead to policies and regulatory changes that have detrimental rather than beneficial impact on a national waste management approach.

Inadequate Data

There are several problems noted with the data base used in the Risk/Cost Policy model. The model considers 83 industrial wastes, of which 80 percent are currently considered as hazardous by EPA. The total volume represents 50 percent of EPA's estimate for annual hazardous waste generation in the United States. For some applications this data base may be reasonable, especially for preliminary screening functions; however, if used to set priorities or tailor regulations this data base may be limited. Large amounts of federally unregulated wastes, which some States define as hazardous, are not included; this could lead to Federal policies that do not consider adequately actual management choices commercially available to deal with these wastes. In addition, there appears to have been no attempt to correlate this data base with the broad diversity in quality of wastes currently being regulated. Thus, results from any analysis using this model would not reflect current needs or problems in hazardous waste management.

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[7] Ibid., p. 1.11.

[8] Ibid., p. 5.7.

[9] C. Haymore, "EPA's Degree-of-Hazard Program," *Waste Age*, January, 1982.

[10] A. M. Gorsuch, statement before the U.S. House Subcommittee on Environment, Energy, and Natural Resources, Oct. 21, 1981.

[11] R. M. Lavelle, statement before the U.S. Senate Subcommittee on Environmental Pollution, June 24, 1982.

[12] U.S. Environmental Protection Agency, *Hazardous Waste Management System: Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*, Office of Solid Wastes, Washington, D.C., 1982.

The data base includes wastes not designated as hazardous and therefore are actually regulated under Subtitle D of RCRA.

1. wastes containing metals that are likely candidates for hazardous designation at some future date;
2. a single nonhazardous waste that might compete for disposal space in subtitle C permitted landfills; and
3. a single metal-fluoride waste that is water soluble and therefore may be classed as hazardous at some future date.

This model treats these wastes as though they are **hazardous** and regulated under subtitle C. The developers of this model apparently assumed that **all wastes** would be regulated under subtitle C in the future. While this situation would be preferable to the exclusionary system currently being used by EPA, **it would seem inappropriate to tailor subtitle C regulations using a data base that does not accurately reflect current management or hazard conditions.**

Although a broad range of technologies are included, actual matching of technologies with particular wastes are rather limited. Furthermore, the choice of technology included in W-E-T combinations is not based on current management practices, but rather reflects engineering judgments about how a waste **might** be treated. For example, incineration is the predominant treatment technology in this data base and is applied as a **single treatment** to 47 of the 83 wastes. Only three waste streams have incineration listed as an option in combination with another treatment technology. Such widespread use of incineration as a **single-treatment** option is not reflected in available data for management of subtitle C wastes.

Chemical fixation/stabilization is the second most predominant, single-treatment technology applied to wastes in the data base. It is listed as a single-treatment option for 36 wastes and in combination with other treatments for 27 wastes. Broad application of chemical fixation/stabilization is not representative of current disposal practices as this data base would suggest.

Costs associated with each treatment and disposal technology are part of the data base. The basis for the estimates of cost was engineering judgment rather than actual costs associated with operating facilities. In addition, differences in such factors as treatability of waste streams, volume, and concentrations of hazardous constituents that will affect costs associated with treatments apparently were not considered.

Inaccurate Assumptions Used in the Model

The Risk/Cost Policy Model attempts to make an enormously difficult analytical problem more tractable by using restrictive and simplistic assumptions about environmental exposure. While OTA would agree that waste, environment, and technology are the three important elements in determining risk from waste management choices, **the assumptions used in the model for each of these elements are so simplistic that inaccurate risk estimates may be expected.**

The concept of determining and using assimilative capacity of surface waters and contamination potential of ground water as measures of environmental or human health risk has merit. The indicators chosen to represent these two concepts, however, have flaws in underlying assumptions and contrary, to a statement in the abstract, **the W-E-T concept as developed in this model does not represent the environmental behavior of waste constituents.**

Unfortunately, the criteria used for assigning high and low levels of assimilative capacity and contamination potential have little relation to the meaning of these two ecological concepts. When considering the first, flow rate is used as the **only** measure and is considered to represent assimilative capability of surface water. The assimilative potential of **any** ecosystem (forest, stream, or lake), however, depends on the capacity of that system to remove, isolate, or destroy a constituent. This capacity is influenced by several factors including:

1. physical factors of an ecosystem;
2. quality and quantity of biota present; and
3. chemical characteristics of a pollutant.

Flow rate is only **one** physical factor of a surface water system that determines distribution of a pollutant and certainly is **not** the **most** important factor. Distribution patterns may increase or decrease the potential assimilation of a constituent into a system. Thus, flow rate cannot be considered a direct measure of assimilative capacity nor can it be considered a reliable measure of surface water contamination.

For example, the actual level of assimilation in a given situation would depend on relative persistence of a constituent, its chemical reactivity within the identified environment, the potential for photodegradation, the ability of biotic populations to degrade it (thus, removing it from food sources), and sedimentation or sorption rates contributing to its long-term isolation. It is conceivable that **both** degradable and persistent constituents in a slow-flowing stream (a characteristic considered in this model to represent low-assimilative capacity and, therefore, high risk) could present the same level of risk. If the persistent compound were isolated from human contact by burial in sediment or accumulated in nonedible aquatic animals, the risk for human exposure would be minimal. High-assimilative capacities (and therefore low-risk levels) are attributed to those locations that discharge into fast-flowing streams, large estuaries, or lakes. However, a persistent constituent could be discharged to a lake, bioaccumulated through the food chain, posing an increased risk to human populations. **Thus, use of flow rate as the sole measure of surface water contamination can hardly be considered as representative of real conditions.**

There are similar problems with criteria for assigning high- and low-contamination potential of ground water sources. The model defines risk in terms of an adverse effect on human health and does not consider effects on the environment. Therefore, it seems misleading to classify an environmental setting in which drinking water standards have been exceeded as a low risk. In addition, the simplistic, dichotomous characteristics of soil permeability that are used as indicators for contamination potential seem unduly rigid and ambiguous. It is not clear how these relate to real conditions of either natural soil profiles or engineering designs of a facility. Many other factors found in subsurface environments influence levels of contamination potential.

The risk/cost model uses population density as an indication of a population at risk. The number of people residing near a site, however, has little meaning for the probability that an adverse effect will occur, the generally accepted definition of risk. The chance of **observing** the effect is greater with larger populations, but the risk to individuals and the proportion of a population likely to be affected are not changed by density. This is a factor that EPA consistently ignores in many of the risk assessment models.

This misconception of risk suggests that EPA does not understand the importance of **actual dose received by a population.** The density within some radius of a waste site is not relevant. **Only that group of individuals receiving a particular dose is the population at risk;** it can be either nearby or far-removed from a site of contamination. Also, the exposure may represent an acute situation—i.e., one single dose, or a chronic situation with several exposures occurring over time. In addition, the dose may vary considerably. Such variations may result from different levels of intake or routes of exposure (e.g., amount of water consumed daily), variation in concentration levels for each intake, and variation in type of chemicals for each intake. Moreover, there is the additional problem that sensitivities of specific individuals to chemicals can vary greatly.

The concept that higher population densities result in greater risks is wrong. Population density is not an adequate indicator of the likelihood of individuals being exposed to a hazardous constituent. It is quite conceivable that only a few people in an urban area would be exposed (e.g., if the major source of drinking water is not drawn from the contaminated site); in contrast, if all local wells are affected, everyone residing in a low-density area could receive contaminated water. If the exposure is indirect (as in distribution of a pollutant in food), density becomes even less important.

Methodology

Overall risk scores are compiled using measures representing waste, environment, and technology as discussed above and are represented logarithmically. Factors in the scores include:

1. **waste**—an inherent hazard score and an exposure score for either air, surface water, or ground water;
2. **environment**—adjustments to exposure scores based on population density, assimilative capacity, and contamination potential; and
3. technology—adjustments to a final risk score based on release rates estimated for selected treatment/transportation/disposal technologies.

Inherent hazard score is defined as the probability of a response per unit of intake. This score is determined for 140 compounds considered to be potentially hazardous constituents of the 83 waste streams. The scoring system used for assigning inherent hazard is based on identifying a minimum effective dose (MED) for each compound. An MED represents the smallest amount of a chemical required to produce an effect in a laboratory population. This effect could range from skin rashes to death. Therefore, each MED represents some minimal level of response; for example, if the following doses are identified for three hypothetical chemicals:

Chemical	*MED*	*Effect*
Chemical A	100.00 mg/kg body weight	X
Chemical B	3.00 mg/kg body weight	Y
Chemical C	0.01 mg/kg body weight	Z

It would indicate that some effect X is noted for chemical A in a laboratory test population only after administering a dose of 100 mg/kg; chemical B and C produce effects that are qualitatively different from chemical A and at much lower doses. Also, because the effects resulting from an exposure are different for C and A, these MED values do not imply that C is more toxic than A. Such an interpretation is possible only if the effects of both chemicals were identical.

Once a human MED has been identified or calculated from animal data, this dose is divided by a factor of 10. Because an effect resulting from low doses usually can be detected in 10 to 30 percent of the test population, an assumption made in the model considers that this division will represent an approximation of that dose which would "yield a 1-percent probability of producing adverse effects," in the population at risk. An inherent hazard score is then assigned for this value. The scale for the inherent hazard score has been set arbitrarily to represent an order of magnitude difference in each unit change—i.e., a score of 2 represents an inherent hazard that is 10 times greater than a score of 1.

The score, however, may be misleading as the model differentiates among doses not quality of effect—e.g., cancer is considered equal to skin rashes. Thus, although the doses represented by two scores of 2 and 3 may be 10 times different, the quality of effects could be reversed; the effect for a chemical with a hazard score of 3 (low dose) may represent skin rashes, while the effect for a chemical with a score of 2 (higher dose) could be death.

In addition to an inherent hazard score, an exposure score is assigned for each compound for one of three exposure routes (air, surface water, or ground water), primarily based on half-life of the chemical. In assigning this score, some consideration also is given for bioaccumulation potential (in surface only), potential removal by conventional water treatment (in surface water and ground water), and adsorption to solid surfaces (in ground water only). It should be emphasized that transport potential of a compound is considered equal to degradation. Therefore, if a constituent is highly volatile and might be transported readily from water to air, the constituent is considered to be degradable in water and the half-life relatively short. However, there are several circumstances where a volatile compound discharged into water would not be readily transported to air—e.g., is adsorbed onto deep sediment or ingested into biota.

Certain modifications are made to individual media exposure scores based on the three environmental indicators previously discussed.

1. Modifications to the surface water exposure score for assimilative capacity **increase** the score by one unit (one order of magnitude change) for low assimilation (i.e., low-flow rate) and **decrease** by one unit for high assimilation (i.e., high-flow rate or large volume of water). Such factors as actual concentration or amount of compound being discharged and the volume of water within which the compound is diluted (for low assimilation) are not considered.
2. A similar problem exists when considering modifications for ground water contamination. Velocity of ground water flow is the deciding factor. High velocity **decreases** a ground water exposure score by one unit for compounds with half-lives greater than 10 years. If the velocity is very slow, compounds with half-lives of 100 years or greater have exposure scores **increased** by one unit. The actual potential for risk in this situation, however, would depend, in part, on distance traveled prior to human exposure. Circumstances could arise where distances are short enough that human exposure would be possible, particularly for compounds with half-lives of 10 years. Also, there are documented cases when contaminant plumes do not move at the same rate, or even the same direction as the ground water flow.[13]
3. A value judgment is made that **all** exposure scores (air, surface water, and ground water) should be adjusted according to density of nearby populations. If density is high the score is **increased**, thus, the overall risk value is increased. If population density is low, the score

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[13] David Burmaster, "Critique of the Monitoring Provisions in EPA's Interim Final Regulations for Hazardous Waste Landfills," OTA Working Paper, 1982.

> is **decreased.** Unit changes established for the model are illustrated in table 7B.3 and reflect a consistent bias **against rural areas.**

This modification scheme gives disproportionate and unjustified weight to dilution capacity and size of populations without regard to the fate of compounds in each medium.

Costs for each treatment, disposal, and transportation technology were estimated based on the "typical" facility. For treatment technologies these estimates were further rounded-off to a value closest to the boundaries set in the cost score. These boundaries represent a difference of two between scores. (These scores are based on log 2.) For example, a cost score of 3 represents technology costs that are two times greater than a cost score of 2. No attention was given to the fact that these costs would vary depending on the waste being treated.

There is a potential inability to discriminate among the W-E-T combinations solely on the basis of cost in a manner that has real meaning. Given two hypothetical W-E-T combinations, W-E-T 1 and W-E-T 2, the costs associated with the latter must be twice as large as the former before they will be considered different in the model. Because of the way costs have been allocated to various technologies in the data base, it is possible that no differences will be observed when using the same technology for two different wastes. Likewise, it is unlikely that differences in costs for different technologies and the same waste will be large enough to merit a change in cost score. Because costs do depend on characteristics of the waste, real values, however, might be very different when comparing the use of two different treatments for one waste.

Misleading Results and Conclusions

As the model currently is formulated, there are certain misleading outcomes that could have serious ramifications in setting RCRA policy and regulatory reforms. Concentrations of a specific constituent can vary considerably among wastes found in the data base; such differences, however, are not reflected in the inherent hazard score. For example, lead is found in waste from paint production and in wastes from metal production; the concentration factor for the first is 0.01 and for the second, 0.03. Although there is three times the amount of lead in one waste, the inherent hazard score assigned to each would be the same. Differences in concentration would only be recognized if the treatment process affected original levels. More realistic differences in hazard and perhaps in the overall risk might be obtained if the inherent hazard score were adjusted for differences in constituent concentrations in the waste.

Table 7B.3.—Unit Changes for Population Density

	Air			Surface water			Ground water		
Half-life	H	M	L	H	M	L	H	M	L
3 minutes	+2	+1	−1						
30 minutes	+1	+1	−1	+1	−1	−2			
6 hours	+1	0	−1	+1	−1	−2	+2	−1	−2
3 days	0	0	0	+1	−1	−2	+2	+1	−2
30 days	0	0	0	0	0	0	+2	+1	−2
1 year	0	0	0	0	0	0	+2	+1	−2
10 years	0	0	0	0	0	0	+2	+1	−1
100 years	0	0	0	0	0	0	+1	+1	−1
1,000 years	0	0	0	0	0	0	0	0	−1

KEY: H—high density, M—medium density, L—low density.

SOURCE: ICF, Inc., 1982.

A major outcome of this model is that for any given waste, risk scores calculated for surface and ground water **decrease** from high- to low-population density, as illustrated in table 7B.4. Thus, the lowest risks, irrespective of waste type or technology choice, will always be those areas with low-population densities. The implication of this use of population density for determining overall risk is alarming. **When more people reside near a malfunctioning waste site, that site would have a higher priority or would require more stringent control technology than a site associated with a lower density of people, regardless of the actual level of hazard or degree of exposure.** Determining policy and regulatory reform on the basis of variations in population density (urban v. rural) poses difficult political and ethical questions.

Misleading results about risks can arise in another way also. For example, determination of surface water exposure scores for two hypothetical chemicals give the following results:

Chemical A, half-live = 3 days	2		2
High-population density	+1	Low population	−2
Low-assimilative capacity	+1	Low assimilation	+1
Modified exposure score	4		1
Chemical B, half-life = 1 year	4		
High-population density	0		
High-assimilative capacity	−1		
Modified exposure score	3		

Although chemical A could be discharged into water with low assimilative capacity (e.g., a stream with a low-flow rate), the location near an urban area results in an exposure score **four orders of magnitude** as high as that in the rural environment. Because chemical B is discharged into surface water with high assimilative capacity (e.g., a stream with a high-flow rate), it has a lower score than chemical A even though chemical B is considered more persistent. A situation could exist whereby

Table 7B.4.—Differences in Risk Score for Twelve Environmental Settings With Example Waste Streams

EPA No.	Constituents	Media	Risk scores by environmental setting[a] 1	2	3	4	5	6	7	8	9	10	11	12
K060 Amonia still lime sludge from coking operation	Arsenic	A	9	9	9	9	9	9	9	9	9	9	9	9
		S	13	13	11	11	13	13	11	11	13	13	11	11
		G	13	11	13	11	13	11	13	11	12	10	12	10
	Phenol	A	7	7	7	7	6	6	6	6	5	5	5	5
		S	7	7	5	5	5	5	3	3	4	4	2	2
		G	11	9	11	9	11	9	11	9	10	8	10	8
	Cyanide[b]	A	11	11	11	11	11	11	11	11	11	11	11	11
		S	6	6	4	4	4	4	2	2	3	3	1	1
		G	12	10	12	10	12	10	12	10	11	9	11	9
	Naphthalene	A	5	5	5	5	5	5	5	5	5	5	5	5
		S	3	3	1	1	1	1	−1	−1	0	0	−2	−2
		G	8	6	8	6	8	6	8	6	7	5	7	7
K073 Chlorinated hydrocarbon waste from chloralkali process	Chloroform[b]	A	8	8	8	8	8	8	8	8	8	8	8	8
		S	5	5	3	3	3	3	1	1	2	2	0	0
		G	10	8	10	8	10	8	10	8	9	7	9	7
	Carbon tetrachloride[c]	A	11	11	11	11	11	11	11	11	11	11	11	11
		S	5	5	3	3	3	3	1	1	2	2	0	0
		G	10	8	10	8	10	8	10	8	9	7	9	7
	Hexachloroethane	A	8	8	8	8	8	8	8	8	8	8	8	8
		S	3	3	1	1	1	1	−1	−1	0	0	−2	−2
		G	8	6	8	6	8	6	8	6	6	4	6	4
	1,1,2 Trichlorethane	A	6	6	6	6	6	6	6	6	6	6	6	6
		S	3	3	1	1	1	1	−1	−1	0	0	−2	−2
		G	8	6	8	6	8	6	8	6	7	5	7	5
	1,1,1 Trichlorethane	A	7	7	7	7	7	7	7	7	7	7	7	7
		S	3	3	1	1	1	1	−1	−1	0	0	−2	−2
		G	9	7	9	7	9	7	9	7	8	6	8	6
K026 Stripping tails from methyl ethyl production	Pyridine[b]	A	6	6	6	6	6	6	6	6	6	6	6	6
		S	5	5	3	3	3	3	1	1	2	2	0	0
		G	9	7	9	7	9	7	9	7	7	5	7	5
	Phenol	A	7	7	7	7	6	6	6	6	5	5	5	5
		S	7	7	5	5	5	5	3	3	4	4	2	2
		G	11	9	11	9	11	9	11	9	10	8	10	8
K025 Still bottoms from nitrobenzene production	2,4 Dinitrotoluene[b]	A	6	6	6	6	6	6	6	6	6	6	6	6
		S	6	6	4	4	4	4	2	2	3	3	1	1
		G	10	8	10	8	10	8	10	8	9	7	9	7
	Nitrobenzene[c]	A	6	6	6	6	6	6	6	6	6	6	6	6
		S	4	4	2	2	2	2	0	0	1	1	−1	−1
		G	9	7	9	7	9	7	9	7	7	5	7	5
K002, 3, 5 Mixed metal sludges from paint production	Lead	A	9	9	9	9	9	9	9	9	9	9	9	9
		S	9	9	7	7	9	9	7	7	9	9	7	7
		G	9	9	9	9	8	8	8	8	5	5	5	5
	Mercury[b]A	9	9	9	9	9	9	9	9	9	9	9	9	9
		S	9	9	7	7	9	9	7	7	9	9	7	7
		G	7	7	7	7	6	6	6	6	3	3	3	3
	Thallium	A	9	9	9	9	9	9	9	9	9	9	9	9
		S	7	7	5	5	5	5	3	3	4	4	2	2
		G	7	7	7	7	6	6	6	6	3	3	3	3
K011, 13, 14 Still bottoms from acrylonitrile production	Acrylonitrile[b]	A	8	8	8	8	8	8	8	8	8	8	8	8
		S	7	7	5	5	5	5	3	3	4	4	2	2
		G	13	11	13	11	13	11	13	11	12	10	12	10
	Cyanide	A	11	11	11	11	11	11	11	11	11	11	11	11
		S	6	6	4	4	4	4	2	2	3	3	1	1
		G	12	10	12	10	12	10	12	10	11	9	11	9
	Acetonitrile	A	8	8	8	8	8	8	8	8	8	8	8	8
		S	4	4	2	2	2	2	0	0	1	1	−1	−1
		G	10	8	10	8	10	8	10	8	9	7	9	7

Table 7B.4.—Differences in Risk Scores for Twelve Environmental Settings With Example Waste Streams—Continued

EPA No.	Constituents	Media	Risk scores by environmental setting[a] 1	2	3	4	5	6	7	8	9	10	11	12
K009, 10 distillation residues from acetaldehyde	Chloroacetaldehyde	A	7	7	7	7	7	7	7	7	7	7	7	7
		S	6	6	4	4	4	2	2	3	3	1	1	
		G	11	9	11	9	11	9	11	9	10	8	10	8
	Formaldehyde	A	8	8	8	8	8	8	8	8	8	8	8	8
		S	7	7	5	5	5	5	3	3	4	4	2	2
		G	13	11	13	11	13	11	13	11	12	10	12	10
	Chloroform	A	8	8	8	8	8	8	8	8	8	8	8	8
		G	10	8	10	8	10	8	10	8	9	7	9	7
	Acetaldehyde[b]	A	5	5	5	5	4	4	4	4	3	3	3	3
		S	4	4	2	2	2	2	0	0	1	1	−1	−1
		G	10	8	10	8	10	8	10	8	9	7	9	7
K065 Mixed metal sludges from nonferrous metal production	Lead[b]	A	9	9	9	9	9	9	9	9	9	9	9	9
		S	9	9	7	7	9	9	7	7	9	9	7	7
		G	9	9	9	9	8	8	8	8	5	5	5	5
	Cadmium	A	9	9	9	9	9	9	9	9	9	9	9	9
		S	12	12	10	10	12	12	10	10	12	12	10	10
		G	12	10	12	10	12	10	12	10	10	8	10	8
K041 Sludge from the production of toxaphene	Toxaphene	A	7	7	7	7	7	7	7	7	7	7	7	7
		S	6	6	4	4	4	4	2	2	3	3	1	1
		G	10	8	10	8	10	8	10	8	8	6	8	6

A—Air
S—Surfacewater
G—Groundwater

[a] Environmental settings:
1—high population density
low assimilative capacity
high contamination potential
2—high population density
low assimilative capacity
low contamination potential
3—high population density
high assimilative capacity
high contamination potential
4—high population density
high assimilative capacity
low contamination potential
5—medium population density
low assimilative capacity
high contamination potential
6—medium population density
low assimilative capacity
low contamination potential
7—medium population density
high assimilative capacity
high contamination potential
8—medium population density
high assimilative capacity
low contamination potential
9—low population density
low assimilative capacity
high contamination potential
10—low population density
low assimilative capacity
low contamination potential
11—low population density
high assimilative capacity
high contamination potential
12—low population density
high assimilative capacity
low contamination potential

[b] Constituent selected for use in model based on highest concentration in waste stream.

[c] Constituents having greatest concentration can vary among waste streams; this constituent often has highest concentration.

SOURCE: Office of Technology Assessment.

drinking water is drawn from rapid-flowing streams or that fish from such a stream serve as food for the population; thus, the **actual** risk for chemical B might be greater than chemical A. The fate of chemicals in the environment have important consequences when assessing risks and these are not addressed by the Risk/Cost Policy model. In addition, the effects on human health may not be represented by the relative risk scores. Chemical A may result in a skin disorder and chemical B may reduce the fecundity of females.

In many cases, the total volume of a given constituent can partition among all environmental media and exposure could result from more than one route—e.g., it could be in drinking water and in food sources. The dose received could be greater for a given constituent than indicated by this model and thus, the probability of observing an adverse effect could be greatly increased.

A second outcome of this model is that costs associated with technologies appear to be biased toward land disposal. Because long-term costs (monitoring costs and liability insurance fees) are not reflected in a realistic manner, disposal on land without any prior treatment may prove to be the least expensive for all wastes. Thus, regardless of the waste and selected environmental setting, **a major outcome** of this model may be that **those W-E-T combinations with the lowest risk/cost results will be those associated with low population densities and disposal in landfills.**

A major difficulty in applying this Risk/Cost Policy Model is that EPA has blurred distinctions between roles of policymaker, regulator, and industry in the management of hazardous waste. RCRA policy was established by Congress—i.e., EPA was charged with protecting human health and the environment from adverse effects that might result through mismanagement of hazardous materials. Because of the statutory language, **EPA is constrained from balancing risk and costs. The use of this model in changing or developing new policy appears to be a violation of the congressional intent of RCRA.**

Finally, EPA is attempting to determine which technologies should be used to manage hazardous waste and in assessing costs and risks for each possible waste and technology combination. This perhaps is a task more suited for industry than a regulatory agency. If the Agency were to set goals for levels of acceptable risk or hazard by establishing some type of standard for industry to meet, it could then be left to individual companies to determine: 1) which technology is to be used to meet the standard, and 2) at what cost. For EPA to do an adequate determination of the W-E-T combinations and evaluate them for risk and costs requires enormous commitments of time and money on the part of the Federal Government. If each industrial entity were to do its own specific assessment, the cost could be internalized within the industry and not be a drain on limited governmental resources.

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